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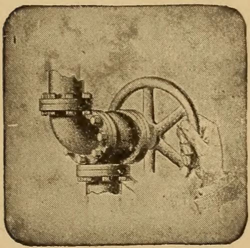

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Jeremiah Head

PAST PRESIDENT OF THE BRITISH INSTITUTION OF MECHANICAL ENGINEERS.

CASSIER'S MAGAZINE.

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BURNING ANTHRACITE CULM AND OTHER LOW-GRADE FUELS FOR STEAM RAISING.

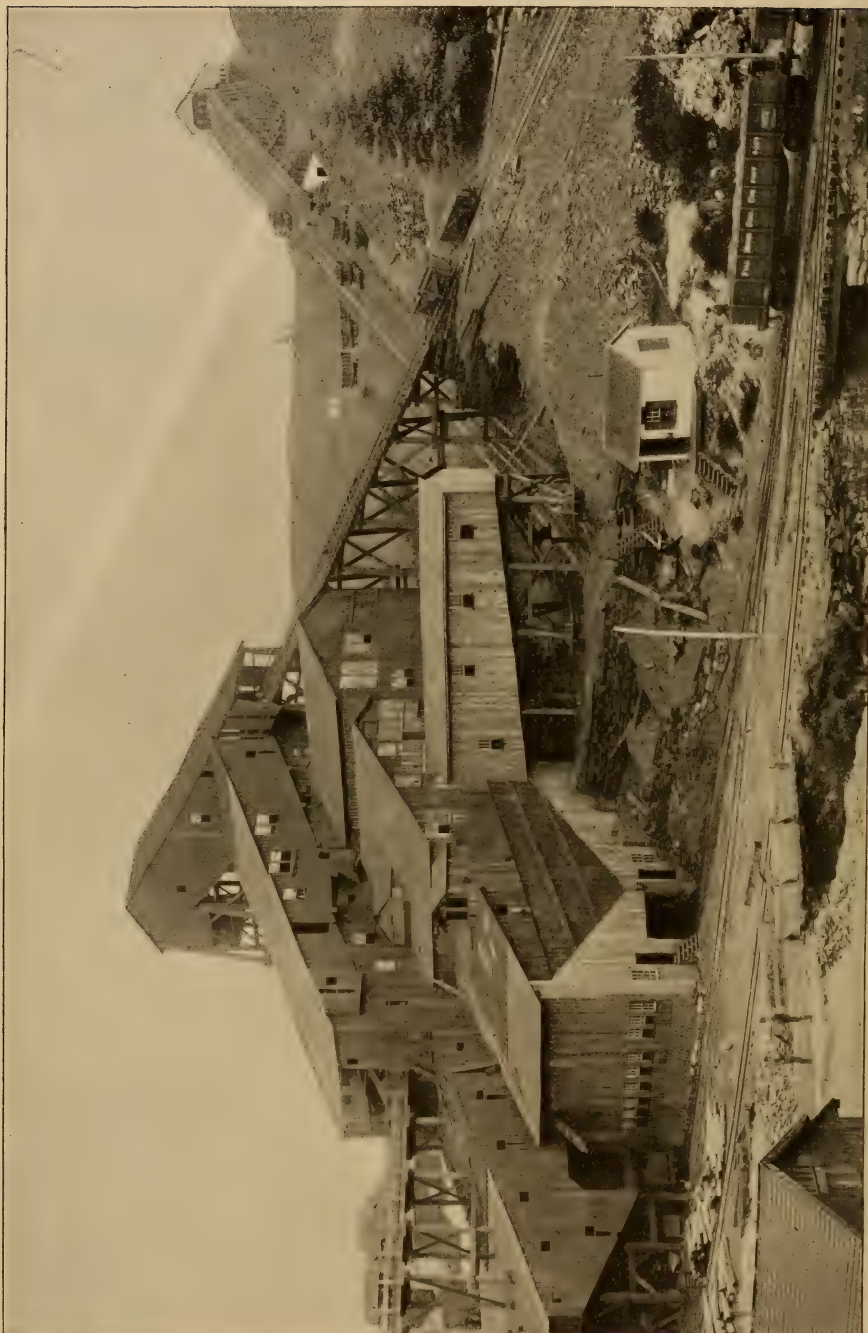
By John R. Wagner.

IT is only a short time ago that all eyes were turned to the development of cheap power by the utilisation of the gigantic water falls at Niagara, and yet, even now, attention is being turned into a new direction—towards the vast storehouses of energy in the American anthracite coal fields in the shape of the immense accumulations of waste coal known as "culm."

The term culm is very elastic, and has often been applied to any mixture of anthracite below that known in the market as pea coal, or anything mixed of sizes from ⅝ inch down to dust. Before discussing the various appliances and systems of utilising culm, I will define this product, as we often hear of the successful burning of culm, which, upon investigation, is found to be a very much different fuel from what was expected.

It has long been understood that anthracite coal will give the best results

A TYPICAL CULM BANK.



A COAL BREAKER IN THE ANTHRACITE REGIONS.

in burning when it is of a uniform size. Twenty-five years ago the market was already supplied with seven sizes—lump, steamer, broken, egg, stove, chestnut, and sometimes pea coal. The operators or coal miners at that time attempted to do away with this large number of sizes, together with the buildings known as "breakers," and to have but two or three sizes, and to impress on the minds of the consumers that they were paying for the loss occasioned by breaking the coal into so many sizes. The trade, however, insisted on getting what it wanted, and not then knowing how to burn, for steam purposes or otherwise, anything smaller than pea, and sometimes chestnut, all below this size was hauled out and stocked in large piles, constituting the present culm banks. Many of these banks contain pea coal mixed with all the smaller sizes, varying from that down to dust.

In the earlier days of anthracite mining, when much pea coal was yet thrown on these banks, only the purer coal was taken from the mines, carrying with it very little slate; consequently these culm banks prove to be low enough in impurities to become a good steam fuel, and which could be furnished in the boiler house of manufacturers in many localities in the anthracite region at a cost not exceeding 50 cents (2 sh.) per ton. There are, of course, many banks where this culm was at the same time mixed with slate and other refuse, which it would not pay to separate. More recently, culm banks would be those containing nothing larger than buckwheat coal, and others, again, containing nothing larger than No. 2 buckwheat, also called rice. Again, some of the coal companies would now call culm that which they could not sell as buckwheat, but which had part of the dust washed out.

To give an idea of the actual size of the small prepared anthracites, I might mention that the following are the most generally used diameters of the perforations in the screens through and over which these sizes are made to pass: Pea coal passes through ⅞ inch and over 9-16, occasionally ⅝ inch; buckwheat, through 9-16 or ⅝ inch and over ⅜ inch; No. 2 buckwheat (rice, bird's eye), through ⅜ inch and over 3-16 inch, occasionally ¼ inch; No. 3 buckwheat (barley), through 3-16 and over 3-32 or 1-16 inch; bird's eye, through 5-16 inch and over ⅛.

That which passes through 3-32 or 1-16 inch is properly regarded as dust. When investigating the subject of burning culm by means of the appliances offered to the trade for the purpose, such data as a clear idea of the exact size or what percentage of each of the above sizes it contains, the proximate analysis of the coal, the pressure of blast under the grate and the draught over the grate and in the stack, the weight of coal consumed per square foot of grate per hour, and the composition of the ash as dumped into the ash-pit, are necessary to enable us to compare a certain system with others with which we are familiar.

Preparatory to a description of the various appliances for burning the smaller sizes of coal, I will give the principal requirements. These are pretty clearly understood, but the fulfillment of them is not. The question of burning low grades of fuel, such as anthracite culm, barley, rice, bird's eye and buckwheat, breeze or coke dust, bituminous slack, etc., is one mainly of undergrate air blast and involves the following features:

1st. Undergrate blast, produced by fan or steam jet.

2d. Large grate area.

3d. Grate so constructed as to constitute a plane surface; that is, without narrow grooves or depressions where an appreciable amount of coal could lodge.

4th. Type of grate that will admit of rapid and easy removal of ash or clinker.

5th. Air spaces from 1-16 to 3-16 inch wide, and not more, except for buckwheat or bituminous slack when they may be ¼ inch wide.

6th. Admitting of the cleaning of fires without having the fire doors open

CULM BANKS AT THE TURKEY RUN COLLIERY, PA., U. S. A.

for any length of time; also the dropping of ash into a closed ash-pit.

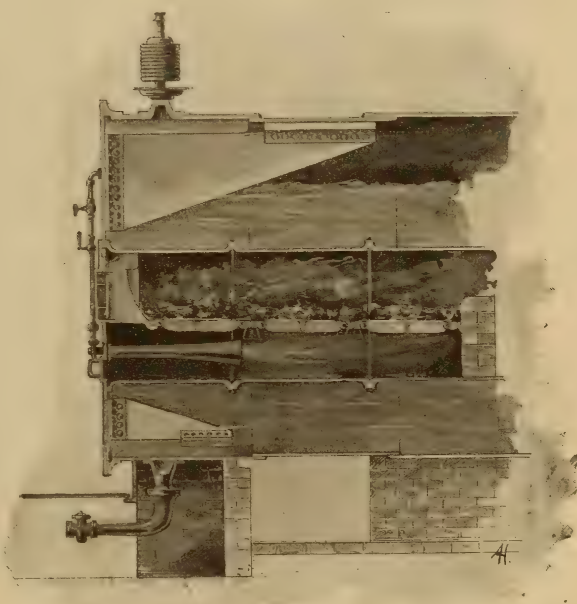
7th. Thin fires and frequent and careful firing. Thickness of bed should diminish with rate of combustion.

8th. Reduction of draught over fire as the value of the fuel or the rate of combustion diminishes, effected by means of a damper in the flue or stack.

The systems that will here be described will include only those with undergrate blast, as there are no others in successful operation where small coal is used. One of the earliest of these, introduced to burn coke dust or breese, house refuse and other low grade fuels is Perret's furnace. The essential feature of this furnace is a forced blast, produced by a steam jet blower, and narrow deep bars, dipping into water to prevent their warping and the adhering of clinkers. The air spaces between the bars are from 1-16 to 3-16 of an inch wide. It has been successfully used in the service of internally fired boilers to burn all low grade fuels. The manufacturers of this furnace, Messrs. Bryan Donkin & Co., of London, do not limit themselves to the use of steam jets for blowing purposes and in their catalogue make the following statement:

"The first cost of putting in a steam jet to produce the blast, instead of a fan and engine, is rather less; but although our furnace thus fitted works far more economically than any other furnace fitted with steam jets (and there are many such) the economy is not so great as when a fan is used; besides this, all steam jets are noisy." This system has been in use in England since 1885.

A furnace similar with respect to air supply, is that known as Meldrum's forced draught and waste fuel furnace. This furnace, patented 1889, is a later rival of the Perret furnace, and its distinctive feature is that of the construction of the steam blower, the curves in the main blower tube being constructed according to the principles of hydraulics to counteract the effect of the "contracted vein." The blower consists of a long cast-iron tube, parallel for a portion of its length, and widening out into a trumpet shape at its inner end. A very small nozzle is fixed to the outer end and through it a jet of steam is injected. It is claimed by the patentee that the steam used by this blower does not exceed two per cent., under favourable conditions of combustion, or 3 or 4 per cent. in extreme cases, of the total evaporation. The percentage of the generated steam used would evidently increase as the size of the coal diminished, and would, no doubt, in some cases much exceed these limits.



THE MELDRUM FURNACE, MADE BY MESSRS. MELDRUM BROS., MANCHESTER, ENGLAND.

The Perret and Meldrum furnaces have met with success in many cases, such as internally fired boilers where a restricted grate area prevailed. A lower

THE BOTTOM OF A MINE SHAFT.

grade of fuel could be used, owing to the feature of forced blast. In other cases, when firing good fuel, with only a slight chimney draught, an increased rate of combustion was obtained with the use of either of these furnaces, but also in ordinary furnaces supplied with fan blast. Great claims have been made for them with regard to the successful burning of low grades of fuel, but with the reported quantities of coal consumed per hour per square foot of grate surface, and a pressure of blast equal from ½ to ¾ of an inch water column, it is evident that the fuel was not as small and as difficult to handle as American anthracite culm or No. 3 buckwheat.

In 1876 Mr. John E. Wootten communicated a paper to the American Philosophical Society, describing a "combination of apparatus by which ordinary anthracite coal waste from the dirt banks at the mines can be successfully and profitably burned in the furnaces of stationary and locomotive

boilers.'' The apparatus consisted of what is commonly known as the Wootten wide fire-box with a flat grate consisting of plates with perforations, from ⅜ to ¾ of an inch in diameter, and from 2 to 3 inches from centre to centre. As a substitute for the ordinary exhaust nozzle and draught Mr. Wootten used an undergrate steam blower similar to that of the commonly used McClave system (described further on) delivering steam and air into a closed ash-pit. This was aided by very small jets of steam in the stack, giving a constant induced draught. Frequent stirring was claimed to be necessary ; yet this grate was said not to allow more than 2 per cent. of the coal charged to fall through the air spaces.

This fire box is still extensively used on many of the American anthracite railroads, especially on the Philadelphia and Reading, which company has about 45 per cent. of their locomotives equipped with it. It is now used with modified grate bars and induced draught produced by a large exhaust nozzle, instead of blowing with steam jets into a closed ash-pit. The sharp exhaust of simple locomotives, when running at a high speed, has a tendency to tear up the fire of small-sized anthracite, and also to draw a considerable amount of the smaller pieces out through the stack, which, in addition to being unpleasant to the passengers, is a loss of fuel.

Recent experiments on the Philadelphia and Reading railroad show that by using compound locomotives, the exhaust nozzles of which are larger, and the exhaust consequently less sharp, and where the amount of steam required to run is less than on simple locomotives, pea and buckwheat can be used even on the fastest trains. For locomotive purposes nothing smaller than buckwheat can be used, even this requiring very close attention and careful firing. Recent statements by the above-mentioned

"BREAKER" BOYS.

railroad show a saving of 70 per cent. in the cost of fuel.

The McClave rocking grate and Argand steam blower were among the first appliances introduced to burn the smaller sizes of anthracite and culm. The system is one of undergrate forced draught, produced by a steam blower, and of rocking bars of excellent design, especially as now put on the market. The main feature of the grate is a rocking motion to the bars, having two functions. The first of these is the cutting off of ash and clinker, which is accomplished by the back edges of the bars, as in Fig. 1, on the opposite page, without increasing the opening between the successive bars.

This result is obtained by giving a certain curve to the back or web part of each bar, and locating the journal a suitable distance from the back and top edges. From Fig. 1 it will be seen that the difference between the radius to the back edge and the shortest radius, is not sufficient to so break up the bed as to allow the fine coal to mix with the ash and thereby cause a waste, but only to rasp off some of the loose ash or small clinkers and to loosen up the bed which is especially adapted to a soft coal fire, when of caking quality. To use this cutting-off movement, the actuating lever is pushed inward, which throws the upper portion of the bars forward.

The second function of the rocking motion is the rapid dumping of the ash into the ash-pit. Fig. 2 shows one of a number of sections, the half or the

SLATE PICKERS IN A COAL BREAKER.

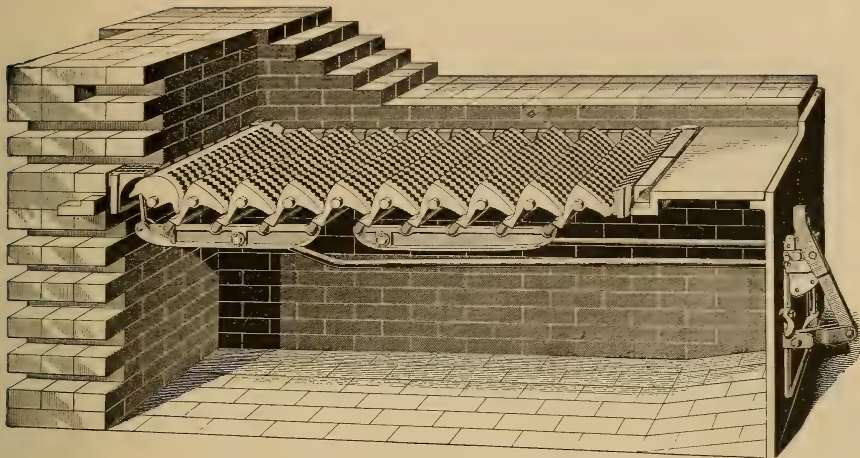


FIG. I.

THE MCCLAVE GRATE, MADE BY MESSRS. MCCLAVE, BROOKS & CO., SCRANTON, PA., U. S. A.

whole of which can be moved at wi by engaging a stop to the levers on the outside, giving either a cutting-off movement or a dumping movement. In the same view the back half of the section is shown in its normal position, while the front portion is in the extreme position, when the dumping movement is used, and the successive bars are arranged with fingers elevated to form pockets to contain the ash and clinkers which will be dropped into the ash-pit when an inward movement is given to the lever. This brings the upper portion forward and into its normal position, indicated by a stop. The great difference in the shortest and longest radius (shown in the cut) will enable the clinker to be rapidly broken up, as they have considerable rise and leverage.

The advantage of dividing the grate into three, four or five sections, each consisting of two portions, lies in the fact that, when cleaning fire, the live coal can be pushed back onto the rear part of the grate, and, if it is not desired to "burn down," the ash and clinker

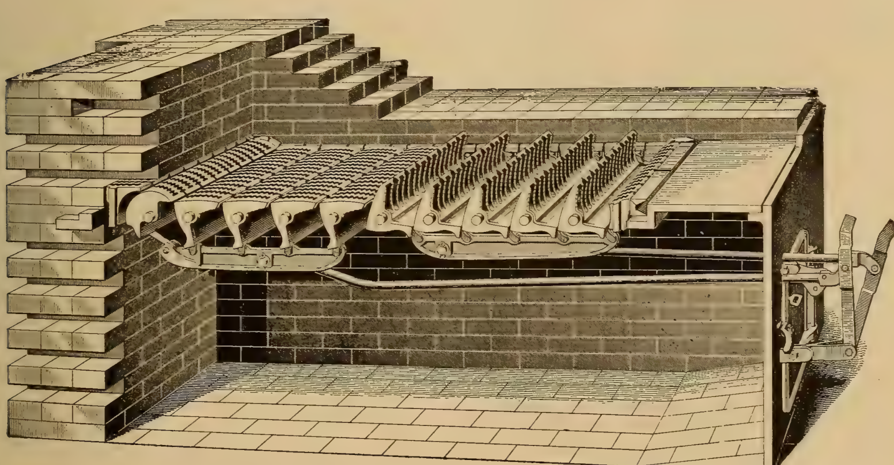
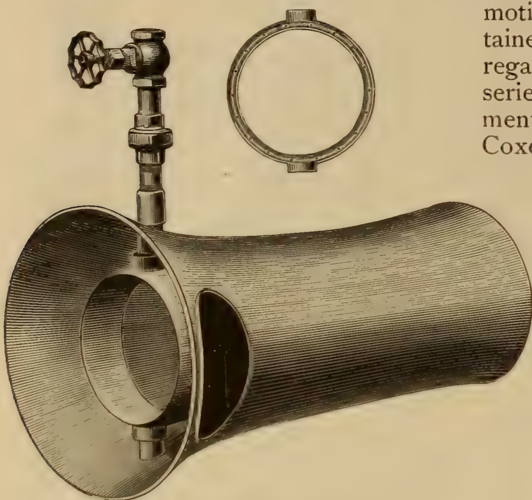


FIG. 2.

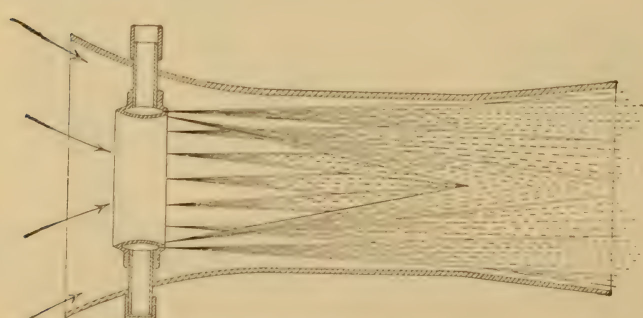
ANOTHER VIEW OF THE MCCLAVE GRATE.

can be instantly dumped off the front portion of each section. The bars of the front portion of the grate having been brought into their normal posi-

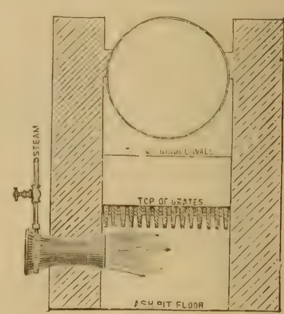


AN ARGAND STEAM BLOWER.

tion, the live coal can readily be pulled forward, and the back ash "burned down," if desired, or instantly dumped into the pit. The live coal or fire can then be distributed over the whole grate and coaled over ; or one section can be cleaned and coaled at a time,



SECTION OF AN ARGAND BLOWER.



AN ARGAND BLOWER APPLIED TO A BOILER FURNACE.

which might be preferred where only a few boilers are fired and where a drop in steam pressure would be objectionable. The foregoing movements can be made with the fire and ash-pit doors closed, thereby preventing any cooling down of the furnace by cold air.

The construction and design of the bars is not only such as to admit of a mechanism by which the two definite motions, above described, can be obtained, but to give the best results with regard to durability. An extended series of experiments at the experimental laboratory of the late E. B. Coxe, with bars of different designs to burn barley or No. 3 buckwheat coal, without allowing the dust to sift through into the ash-pit, led the writer to appreciate the following points of excellence in the McClave bar :

1st. All the metal surface on which the coal lies is in one plane, except the slight wave in it due to the curvature of the bars, with no recesses in which coal can lodge and burn or warp the adjacent prcjecting metal.

2d. The short lengths of metal with sufficient depth to transmit the heat to the pendent or supporting rib, which, in turn, is of sufficient depth to be relieved of its heat by the blast, whereby warping and burning out is prevented.

3d. The curve to the pendant or supporting rib and the position of the journal with reference to the back and top surface, so as to allow a wide range of motion, as in Fig. 1, without leaving

AT THE HOISTING CHUTE IN A COAL BREAKER.

an opening through which coal could pass.

4th. The air spaces can be made small without becoming clogged.

At the time of these experiments the weakest point in the bar was observed to be in the fingers, which would occasionally have a portion knocked off by the careless dropping of the hoe used in spreading the live coal when cleaning. This weakness has been eliminated by casting a tie between each pair of fingers, which also afforded a more equal distribution of the air. The top journal bearing bar has also been improved to better allow for expansion.

The steam blower, in its improved form, is shown on the opposite page. Instead of the perforated ring, formerly made of cast iron and of circular cross section, it is now made of phosphor bronze and is of the cross section, shown, which allows the air to have better access to the steam jets. With this metal the size of the small openings will be better maintained, and by making the supply pipe from the steam main of brass, the tendency to clogging by particles of rust is obviated. This system of bars and blower has been on the market for a period of ten years, and has a wide distribution outside of the coal regions, giving very satisfactory results.

For hand-fired grates there certainly seems very little chance for any marked improvement over the McClave grate as now constructed. It must, however, be borne in mind that the McClave or any other grate will not burn the fine coal, but that it is effected by the air that passes through the bed of fuel, and that the best a grate can do is to hold the fine coal, present the best form of air spaces, to have the distribution of metal such as to best resist warping and burning, and to admit ot rapid, easy and economical cleaning of

AT THE "TIP" OF A BREAKER.

fires. Having then a grate fulfilling all these necessary conditions, the fuel-bed must be so managed as to allow the necessary air to pass through or the expected results will not be obtained. This involves the carrying of thin and uniform fires, with frequent coaling.

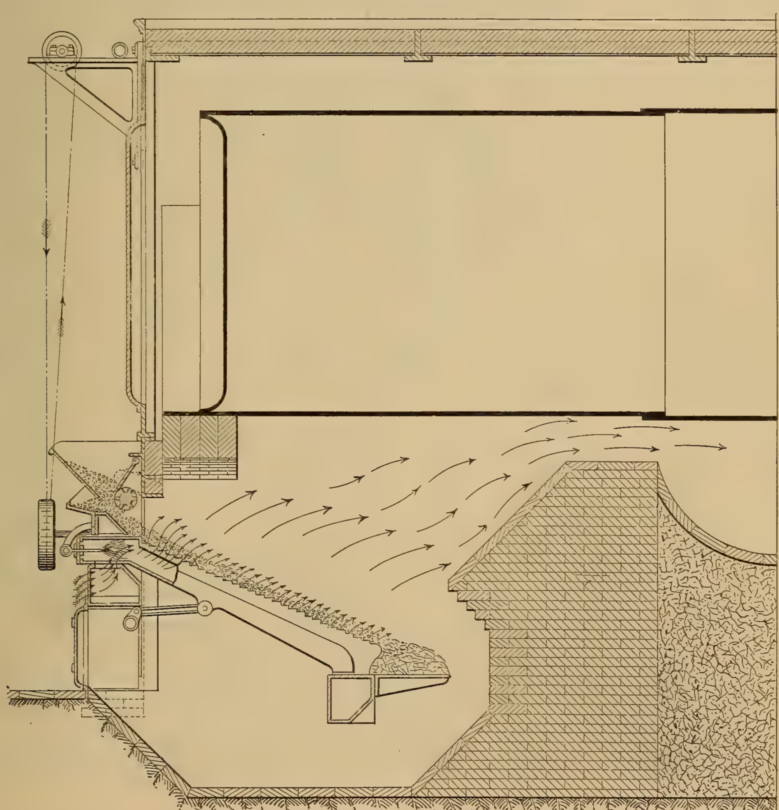
One of the difficulties experienced in the attempt to burn barley and rice coal with a strong undergrate forced blast was due to the formation of blow holes or miniature volcanoes. When these were once formed, the air would continue to blow through, producing a very intense local heat by the excessive blast and resulting in the formation of clinkers at these points. After a number of these blowers are formed, the air no longer passes up through other portions of the bed, although, ultimately, the production of ash in the entire bed will result, radiating from these blowers outwardly. The Leisenring shaking grate, recently put on the market by the Leisenring Manufacturing Company, of Scranton, Pa., is a compromise between the McClave dumping grate and a stationary grate with undergrate

steam blowers. It has a tendency to overcome the difficulty due to this blowing.

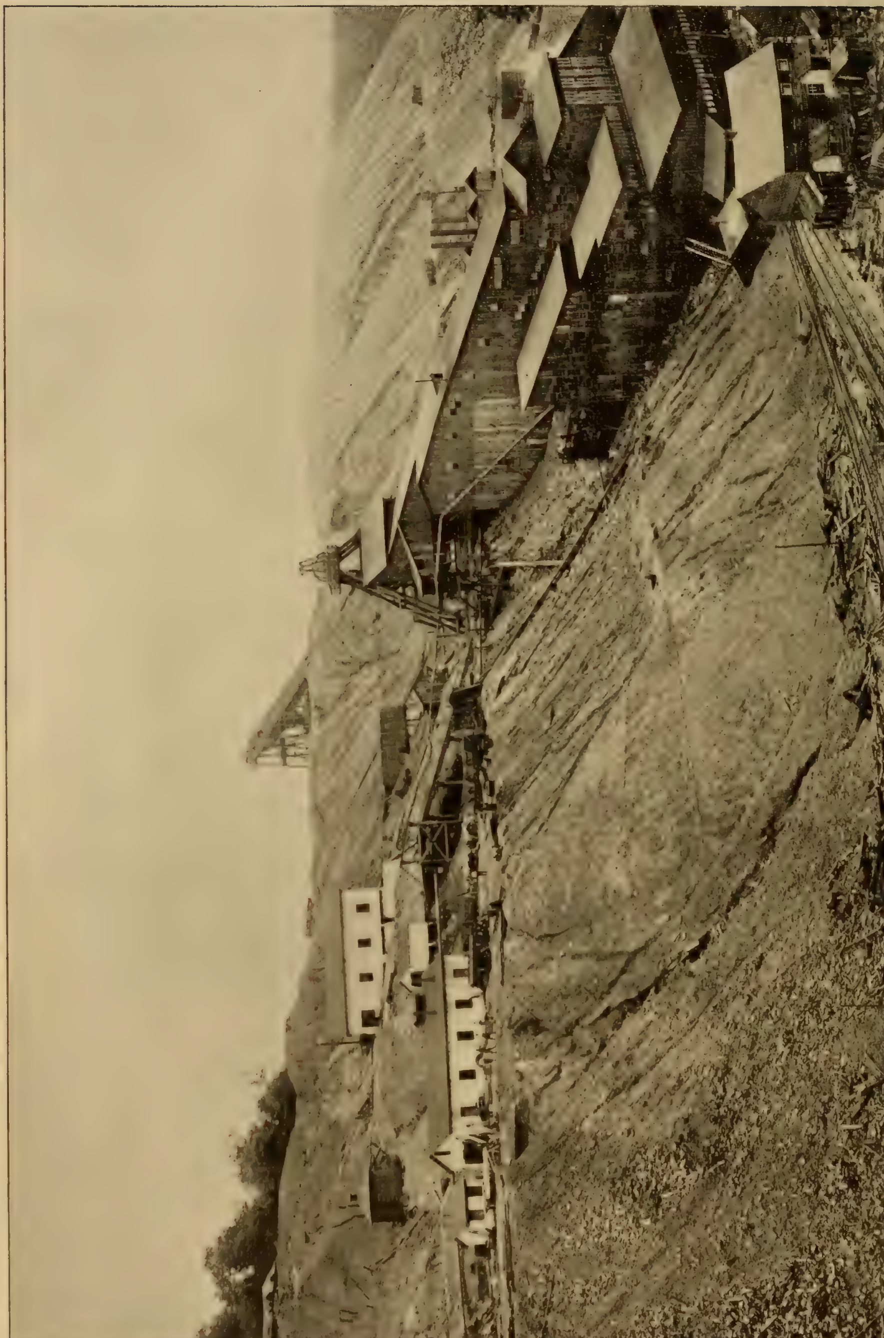
The grate consists of a series of fixed bars with central webs from which fingers project on both sides, two adjacent sections of which leave a space and form a shallow trough tapering to the centre to receive a sliding bar of similar construction. The fingers of this are wide enough to completely cover the spaces between the lower fingers. By the shifting of the upper section on the lower one it can be made to offer an air space of from 40 per cent. to nothing. The sections seven inches wide and the alternate bars move in opposite directions, each having a movement of two inches.

By an occasional movement of the bars, the blow-holes above mentioned will become closed and others will be formed, so that the bed may be consumed uniformly in all portions before cleaning time. Where the coal is not of a clinkering character a part of the ash may, by this movement, be sifted through the lower bars. In strongly clinkering coals, the cleaning of fires would, however, be effected in the same manner as in stationary grates. The blast under the grate is produced by jet blowers, somewhat similar in principle to the McClave.

The advantage of using steam jets to produce the air blast is that they lessen the tendency to the formation of hard clinker, and increase the life of the grate bars, and that the first cost and subsequent repairs of the undergrate forced draught system is less than that of the fan. Another effect of the introduction of steam into a furnace is to give to the process of combustion the



THE WILKINSON AUTOMATIC STOKER, MADE BY THE WILKINSON MFG. CO., BRIDGEPORT, PA , U. S. A.



THE BAST COLLIERY, NEAR ASHLAND, PA., U. S. A.

nature of that in making producer gas, and thus giving more volume and a longer flame than is ordinarily produced with anthracite coal. Such a flame is in some boiler settings an advantage, but always requires sufficient space and time for the gases to mix with the air and to burn before they leave the final water heating surface. Where there is a weak chimney draught and hard forcing of the fires with the steam blower, there is danger that some of the gases escape combustion, and re-ignite above the stacks, which is often seen, especially where short stacks and high temperatures of escaping gases prevail.

The same thing might occur, though not visible, when the boilers all discharge into one large but low stack, in which they might burn in the stack with the air coming from a boiler furnace where there was an excess of air, although the burning of the gases would give no available heat, as it would be beyond any heating surface.

The question as to the economic evaporation per pound of fuel and the relative economy between forced draught produced by the steam blower or by a fan blower need not here be discussed, as the saving effected in burning small coal by any system is not due to a more complete combustion by one system than in another, but is entirely due to the difference in the price of fuel and the ability to burn, in sufficient quantity, what would be in many cases a waste product. The question as to what advantage, if any, in economy, the fan blower has over the steam blower will, no doubt, be settled by experiments within the next year or two. Indications now point to a greater consumption of steam by the steam blower than by the fan blower, one reason being that in the case of a fan there is no power consumed except the friction of the fan, when there is no air propelled or passing through the fuel, whereas in the case of the steam blower the same amount of steam issues from the blower, whether there is any movement of air through the fuel or not. From this it would appear that the smaller the fuel the more efficient would the fan become as compared with the steam blower.

The firing of culm or the smaller anthracites with admixture of bituminous coal is worthy of consideration. Very good results are obtained both as far as capacity and economy is concerned, by sprinkling several hundred pounds of culm, more or less spread out on the floor, with about eight per cent. of crushed bituminous coal. This way of mixing will enable the firemen, while coaling the fire, to do better than if the two coals were intimately mixed, as he will instinctively take a shovelful from such a portion of the pile, either rich or lean in soft coal, as will suit the particular spot on which it is to be thrown. The bituminous coal will immediately become more or less incorporated or agglomerated with the anthracite, preventing the dust in the latter either to blow out through the flues or drop through the grate. It also serves to keep the bed more open, and thus increases the rate of combustion. In this manner culm and rice coal are fired, giving results as to capacity of boiler unable to be approached by the same anthracite alone.

At centres where yard screenings or screenings from the docks can be obtained, its use will show an appreciable economy when mixed with from 8 to 10 per cent. of bituminous, even when its cost is fifty cents (2 sh.) a ton more than the screenings. This method also has the advantage of producing no more smoke than would be allowable by the ordinary smoke ordinance. Forced draught is also required with this method of firing, but as the mixture is more free-burning, it need not be as strong as with the anthracite alone of the same size.

The Wilkinson automatic stoker is one of the class which may be called "inclined reciprocating stokers." On page 15 is shown a sectional elevation of it as applied to a horizontal return tubular boiler. This stoker consisted, until recently, of a series of hollow, inclined reciprocating grate bars, a worm gear and toggle-joint mechanism for oper-

A CULM BANK AND CONVEYOR.

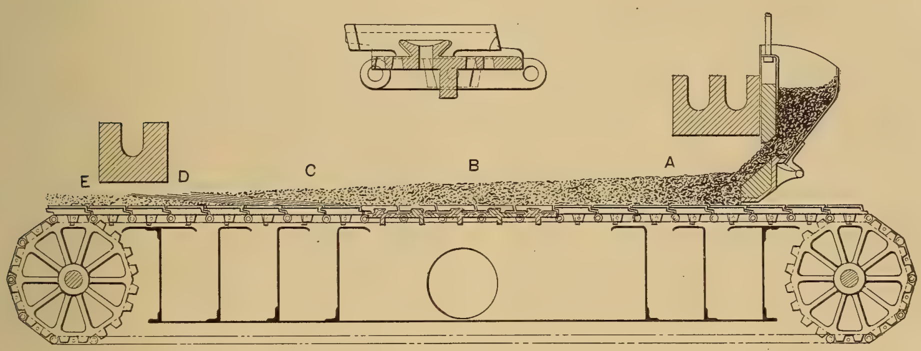
ating them, a series of steam jets, one blowing into each bar, a feed hopper in which revolves a feed roller, a hollow casting on which the lower ends of the bars reciprocate, and of the stationary table which is supported by this hollow casting.

The grate bars are a series of hollow castings, approximately of rectangular cross section, 4½ inches wide by 6 inches deep, placed side by side and inclined towards the bottom of the furnace at an angle, suited to the repose of the fuel (28 to 30 degrees). The upper end, which is open to admit the blast pipe, projects through and is supported by the stoker front. The lower end slides on and is supported by a hollow casting termed the bearer bar, as shown in the cut. Throughout the inclined length and in the face or upper side of the bar, is cast a succession of steps. Through the rise of each step a vent or tuyere is provided, through which the air and steam issues, passing up through the bed of fuel. To move the mass of fuel forward and to keep it open, the alternate bars move in opposite directions, being connected in two series. The motion is constant and uniform, the one series being always ready to advance and carry the fuel forward at the instant the other is receding. The extent of the movement varies from nothing to 1 and 1¼ inches, being the greater, the smaller the coal.

The revolving feed roll, shown in the hopper, feeds the fuel at a uniform rate from the hopper to the upper end of the grate bar, the continuous back-and-forth motion of the grate bars, thereafter insuring a uniform thickness of the fuel bed. This motion prevents the ash from melting to the bars, or the formation of large clinkers, and causes a slow but gradual advance of the partially consumed fuel to the bottom of the grate, by which time it is consumed, and the ash is deposited on the stationary table, shown bolted to the hollow bearer bar. The ash on this stationary table nearly fills the space between the hollow bearer bar and the over-hanging bridge-wall, thereby producing a partial seal between ash-pit

and furnace and preventing any inrush of air through ash-pit and the consequent cooling of the combustion chamber. The same movement of the bars also forces the ash off the table into the pit, to be removed in the usual manner or by a conveyor of some kind.

The mechanism for effecting the entire operation consists of a pulley, a worm and a worm wheel on one end of the feed roll shaft, on the other end of which it has a crank disk of variable throw which, by means of a link, oscillates the shaft carrying a series of rocker arms. It can, therefore, readily be seen that the power required to drive the moving parts is nominal. The blast is saturated steam, through a



THE COXE AUTOMATIC STOKER, MADE BY MESSRS. COXE BROS. & CO., DRIFTON, PA., U. S. A.

1-16 inch nozzle, into each bar, or one nozzle for every 4½ inches in width of grate. In this form it has given very satisfactory results with buckwheat coal.

This stoker is simple in construction and seems durable and not likely to get out of order. Of course, it is rather soon to judge on this point. Since its introduction in 1892, it has undergone many important changes and improvements, the most recent of which are the use of a closed ash-pit, the manner of introducing the air, and the provision made to introduce a slice-bar to free the bars from clinkers. The ash-pit is entirely closed and without any entrance of air, except that which forces back through the bars or leaks in through the ash-pit front; consequently, there is no necessity for any great care in bringing the overhanging bridge-wall to form a seal with the ash on the fixed extension grate to avoid leakage of air into the combustion chamber at that point.

The air for cumbustion passes through perforations in the outer wall of the wind saddle and up through large openings in its top, corresponding to similar ones in the bars, through which it is drawn and propelled forward by the action of the steam jet, as shown in the cut. By closing the upper ends of the bars with a plate through which the steam jets pass, and by delivering the air in this manner and having a closed ash-pit, both the noise and an excess of air into the furnace is avoided. The cut shows the opening at the base of the fuel hopper whereby a slice-bar may be used to clean every portion of the grate. This is especially important with some coals. The projecting shelf below this opening holds any coal that may escape through it. In dotted lines, immediately above the feed roller, is shown a spout-like projection, one adjacent to each side wall, for the purpose of inserting a slice-bar to remove any clinker that may adhere to the sides, which is however not often the case. These openings are provided with caps or lids, and offer a ready means for examining the condition ot the fire.

From the sectional elevation given, the process of burning will become clear, and it will be seen that the upper

two-thirds of the grate partake of the nature of a gas producer, while the lower one-third is a zone of intense and complete combustion. The reason for this action is: 1st. The upper portion of the bed is so thick and imperfectly ignited as to prevent the air from readily passing through it in sufficient quantity and of suitable temperature to burn the volatile gases there given off. 2d. Steam is forced through the incandescent bed and part of it is decomposed by the latter. With an insufficient air supply accompanied by steam, a certain amount of hydrogen and carbonic oxide is formed. At this stage some of the hydrocarbons also escape combustion. On the other hand, the lower third of the bed is composed of loose ash with only a thin layer of incandescent coal on the surface, through which an excess of air readily passes.

Any excess of air that may find its way into the furnace at the upper end through the hopper, or at the lower end and under the bridge-wall, will become thoroughly mixed with the gases from the upper portion of the grate and thus bring about their complete combustion before passing over the bridge-wall. It will thus be seen that the good results which have been obtained are due to the fact that the producer action of the upper part of the grate serves to counteract any defective working at the lower end, such as may be produced by a leakage of air under the bridge-wall or through the burned-out spots in the ash. This view of the producer action will be somewhat modified by a very recent design, in which the ash-pit is closed.

The Coxe automatic stoker is one of the type known as "travelling chain grate stokers." The travelling fire grate was first patented in England in 1834 by Mr. J. J. Bodmer, and differed from that of John Juckes, patented in 1841, in the manner of moving forward and returning the fire bars, the latter being a travelling chain grate, while in the former's modification of his original grate they were carried along on screws. They were mainly introduced for the prevention of smoke, and tests, made in 1843, showed complete combustion without smoke and a gain of 11 per cent. in economy.

Slack and other inferior coals were successfully burned. The boilers then, being of small capacity, would make the relative cost of these stokers so high as to exclude their introduction. But as boilers are now constructed, in units of large horse-power, the relative cost is diminished, which, together with the question of smoke prevention, has again brought about the introduction of this type of stoker. A number of these chain grate stokers, introduced by Mr. N. W. Pratt, of the Babcock & Wilcox Boiler Co., of New York, are in successful operation with bituminous coal, effecting economy and the complete prevention of smoke.

The Coxe stoker, while patented about the same time as that of the Babcock & Wilcox Co., was not intended for the burning of bituminous coal, but for the smaller sizes of anthracite and culm. The experiments made by the late Eckley B. Coxe to determine the correct principles for burning small anthracite coal economically, proved, among other things, the necessity of having a travelling fire grate on which the coal could be fed, ignited, burned out, and the resulting ash dumped without in anyway disturbing the mass of fuel or mixing fresh coal with it; hence, the application of an old principle to a new purpose.

The construction of the fire grate floor, owing to the absence of caking in anthracite, must be very different from that which may be used for burning bituminous coal. As small anthracite ignites with difficulty, or very much slower than bituminous coal, special provision had to be made for increasing the rate of ignition. Provision had also to be made to submit the bed of fuel, in its different stages of reduction, to different air pressures, as the small particles form a compact bed and do not swell up as in the case of soft coal, thus preventing a free passage of the air; and, further, because with this fine coal the pressure required for it to

pass through the bed, increases very rapidly with the increase in thickness, so that, unless provided against, all the air would pass up through the bed where it was burned out.

The engraving used for the general description of the travelling grate, is not an exact representation of it as built, but is intended more especially to explain the principle of its action and to show how the conditions above referred to are fulfilled. The coal which is brought to the feed hopper by a drag, spout, or any other convenient method, feeds down by gravity over a fire brick, called the "ignition brick," onto the travelling grate. It is then carried slowly at the rate of from 3½ to 8 feet per hour towards the other end.

In the beginning of the operation, the coal on the right-hand side of the furnace is ignited, the other part being covered with ashes or partially consumed coal. When the coal next to the ignition brick is ignited, the latter remains highly heated, and the coal, passing down under the regulating gate, and over this fire brick, becomes gradually heated, so that by the time it reaches the foot of the ignition brick it is incandescent. In some cases the coal becomes hot enough to ignite soon after it passes the regulating gate.

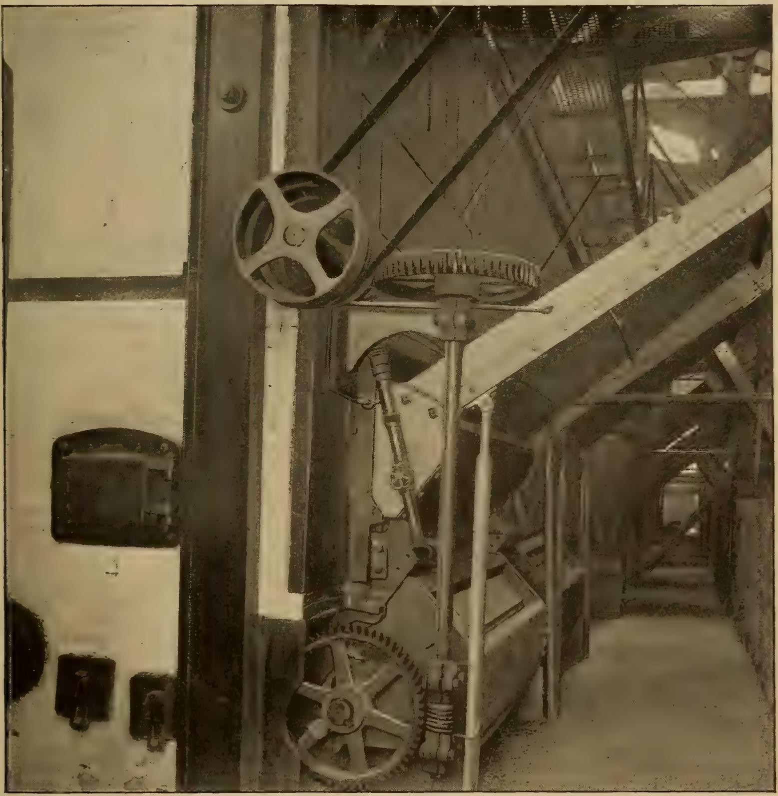
Under the grate there are a number of chambers, made of sheet iron. The air blast from the fan enters the large air chamber. These air chambers are open on top, but the partitions are covered by plates of such width that, no matter what may be the position of the grate bars, there is always one resting upon this plate, so that the air cannot pass from one chamber to another except by leakage along the bars. The result of this arrangement is that if blowing into the large air-chamber with a pressure, say, of one-inch water-gauge, the pressure in the next air chamber to the left would be about ⅝ inch, in the next to that ⅜ inch, and in the next to that ⅛ inch. The pressure in the air chamber to the right would be, say, ⅝ inch, so that the coal when it arrives on the grate is subjected to a pressure of blast sufficient to ignite it, but not too strong to impede ignition. In order to regulate exactly the pressure of the air in each of the compartments, the partitions are provided with registers, by the opening and closing of which the pressure in the air chambers can be varied to suit the conditions.

As the thoroughly ignited coal passes slowly over the large compartment, where the air pressure is a maximum, it burns briskly, continuing to do so during its slow passage over the successive compartments, in which the air pressure is less and better suited to the combustion of the thinner layer of partly consumed coal. The bed continues to diminish in carbon, and to be subjected to less blast, until finally the gentle current of air passing through the consumed bed is only heated and mingles with the carbonic oxide produced in the zone *A* and part of *B*, and converts it into carbonic acid gas. The object is to subject the coal, as soon as it arrives on the grate, to a pressure of blast which is the proper one to ignite it; then to burn it with a blast as strong as will produce the desired rate of combustion, and as the carbon is eliminated and the bed becomes thinner, to diminish the blast to correspond with these conditions. The mass of coal remains all the time in practically the same position and condition in which it was placed on the grate, except so far as altered by the combustion.

This automatic stoking furnace has been in continuous operation, the first three, for a period of three years, night and day, and two more since May, 1893, having in all built forty-one which are either running or in process of erection. About a month prior to the death of the inventor, he made another design which would be adapted equally as well for bituminous slack as for anthracite, involving, however, no changes in the principle, but only in the side frames and omitting the water pan under the grate and the water jackets in the side walls which were used in the earlier furnaces constructed, but which have been found unnecessary. Many other substantial improvements have been made in this new design,

ANOTHER VIEW OF A COAL BREAKER WITH A CULM PILE IN THE BACKGROUND.

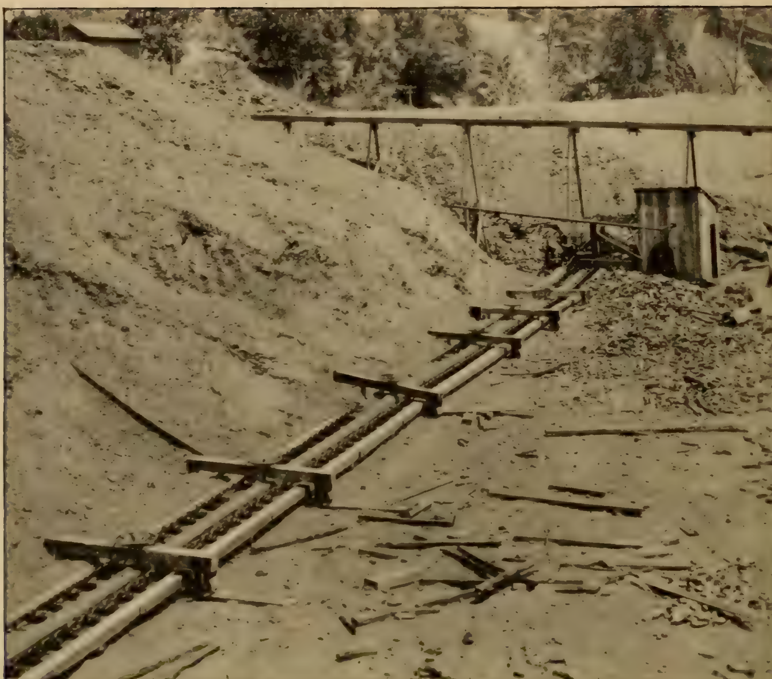
such as the driving mechanism, air pan and grate-bars, which are fully described in a paper read by him last April before the New England Cotton Manufacturers Association and entitled "Some Thoughts Upon the Economical Production of Steam, with Special Reference to the Use of Cheap Fuel." the machinery, the coal and ashes being automatically handled. In the old boiler plant five men were required, even when firing pea coal. Owing to the first cost, stokers will not make such a good showing in small plants, nor where boilers of small horse-power are used, and further, where they are



A BOILER PLANT EQUIPPED WITH COXE AUTOMATIC STOKERS.

On page 23 is a reproduction of a photograph of a series ten of these stokers under Stirling water tube boilers, in operation at the Philadelphia & Reading Coal & Iron Co.'s plant at Mahanoy Planes, in Pennsylvania. The advantage in mechanical stoking lies not only in the ability to burn the cheaper grades of fuel, but also in the saving of labour. In the above plant, for example, only two men are employed,—a water tender and a man to look after run only from ten to twelve out of the twenty-four hours.

In the description of the last three grates, the writer has endeavoured to bring out clearly the requirements for the burning of small anthracite coal by a somewhat detailed description of the merits of the various actions of the grate bars and in the handling of the fuel bed. From what has been said in this description, the reader will be able to decide on the development



A CONVEYOR TAKING CULM FROM ONE OF THE BANKS FOR RE-WORKING.

of grates and furnaces for the utilisation of the low grade fuels and the difficulties to be met with and overcome. The reader, however, still lacks the information to proceed to avail himself of the abundant supply of cheap fuel. This information he must get from some points which follow.

Some definite figures as to cost of fuel at the mines, delivered in boiler-houses, both in and out of the coal regions, and the relative steaming value of the various grades of available cheap fuel would be very desirable, but these cannot now be given as there are so many factors influencing their value. The Scranton, Pa., Engineers' Club undertook a series of boiler tests with a view to furnish manufacturers looking for cheap power with the cost per boiler horse-power in their city. These tests are being made with different grades of fuel, and include the cost of fuel, cost of firing, getting rid of ashes and cost of water. While they have made a number of tests, they are still engaged in making others, which, when completed, will enable them to give to manufacturers and the public fairly conclusive figures as to the cost per boiler horse-power in the American anthracite regions.

Attention will be called to some important facts which must necessarily be given without regard to order or classification. Buckwheat coal, sold at the mines for from 55 to 65 cents (2 sh. 2½ d. to 2 sh. 7½ d.) a ton, can be fired by almost anyone, and by means of undergrate forced blast the rated capacity of the boiler can be obtained, and in good types of boilers the rated capacity can be much exceeded. Rice coal, sometimes known as No. 2 buckwheat or bird's eye, sold at the mines at twenty-five cents (1 sh.) a ton, is also a good steam fuel, but requires for its adoption, in order to get the rated capacity, a reconstruction of the furnace, giving larger grate surface and undergrate forced draught, and often necessitates an addition of new boilers to produce

the required amount of steam. There is no simple and cheap device which can be applied to an existing boiler plant by which rice coal, or smaller, can be made to replace buckwheat coal. Nor has any one yet found a method by which a pound of culm or a pound of barley coal can, by the injection of steam or the introduction of firebrick arches, etc., be made to produce more or as much steam as a pound of buckwheat coal. The economy must be sought alone in the lower cost per ton of fuel. There is a possibility of making considerable saving in the fuel bill and in the firing by the introduction of either of the foregoing automatic stokers, but the expense of their introduction is very often beyond that to which the owners of the boiler plant are willing to go.

The adoption of a cheaper grade of fuel always calls for an extra outlay of capital in the boiler plant. The McClave grate is the cheapest of the efficient grates for the burning of the smaller anthracites, but even this requires a larger grate area and skillful firing. The Wilkinson and the Coxe stokers have the advantage over the McClave grate, that they reduce the number of firemen required to one third, and, in some cases, to twenty-five per cent. of that required in hand firing in these cheaper fuels. But neither of these will show much of a saving unless the total consumption of coal is, say, four tons an hour, and a complete installation of coal and ash conveying machinery is at the same time introduced.

Of course, there are boiler-houses where the tracks are so situated that no machinery is required for delivering the coal, and a convenient location exists for the removal of the ashes by loading them direct into carts. As the firing of smaller fuel requires frequent opening of the doors, it can readily be seen that the automatic stokers will retain the same economy at high rates of combustion as at low rates. When forcing a boiler much above the rated capacity with hand firing, the fire-doors in many cases remain open fifty-five per cent. of the time, which lowers the efficiency materially. Not only should the furnace or grate be adapted to the

CONVEYING CULM FOR FILLING MINE CHAMBERS.

burning of low grade fuels, but the boiler setting should also be modified to conform with the requirements.

While the firing of the rice coal may be adopted without any considerable increase in the boiler plant, the firing of the next size below, barley (No. 3 buckwheat and culm) and such culm as is a mixture of rice, barley and dust, do require a very considerable outlay in furnace as well as boiler capacity, as not more than from one-half to one-third as much of this grade can be burned in the same time and on the same grate surface as in the case of buckwheat. The reason for this, as before mentioned, is the great difficulty which the air experiences in passing through the bed. An inch difference in its thickness requires a considerable increase in the pressure of the air. Chimneys or strong induced draught do very little good with this fine coal, as the leakage over the fire through the boiler front and brickwork will be very large compared to the amount of air drawn up through the fuel.

Culm from old culm banks which contain pea coal and even a little chestnut mixed with dust, while increasing the rate of combustion by an easier passage of the air through it, will not give as good results as an intermediate size containing less of the larger pieces and of the actual dust (through 1-16 inch mesh). The reason for this is that the larger pieces will not be entirely consumed by the time that the smaller particles are. In the case of the more free-burning coals, it is possible with efficient undergrate blast to get nearly the rated capacity out of the boilers with what might be called a dirty rice coal and containing as much as forty per cent. of ash. It would, however, be poor economy to pay any transportation on such fuel as this, even as a gift, or any fuel containing more than twenty-five per cent. of ash. Where it is desired to utilise culm banks with larger pieces of coal and bone, it is necessary to crush it to the size of buckwheat and to remove the actual dust, *i. e.*, all through 1-16 inch mesh.

Where manufacturers see fit to generate steam in the anthracite regions, because of the cheap fuel, for power to be used there or transmitted to the manufacturing centres, the boiler plant should not only be located adjacent to a culm bank, but near and along the tracks of some breaker which is likely to have a coal supply for some time to come, as then the smaller sizes of fresh mined coal can be obtained at the same price as that of the culm banks. This would be the case when there was no demand for these sizes.

From what has been said regarding the burning of culm which contains a considerable amount of dust, it is evident that it will not pay to burn culm or barley coal in preference to rice while the existing difference in price is so slight and where it had to be transported to tide or to such a point where the relative cost would differ by only a small percentage, which would be the case when the transportation would raise the cost to two or three dollars per ton (8 to 12 sh.).

The difference in price which now exists between rice and barley coal is not commensurate with the relative value of the two fuels. When we pass from rice to barley coal or culm containing a large amount of dust, which impedes the passage of the air through the fuel bed, the value diminishes rapidly with the degree of fineness, although the two coals may have the same percentage of fixed carbon and ash. The difference in value between buckwheat and rice coal is much less and not as great as the difference in price, rice coal being, therefore, the more economical fuel, providing the slight change due to the required difference in great area and boiler capacity could be made.

MILL EQUIPMENT.

By Geo. A. Becks, Assoc. M. Inst. C. E.

TO be a competent millwright a man should be familiar with the ordinary methods adopted in designing, constructing, erecting and repairing all classes of machinery, having all the principles involved therein, thoroughly in his mind. He should also be able to calculate with tolerable accuracy the strains to which machinery, shafting and gearing are subjected, quick to observe defects, and have considerable inventive genius to overcome difficulties encountered in the execution of his work. He should furthermore be able to look considerably ahead, so as to make arrangements for the completion of his work without any delays, and should never do work which will have to be undone to admit of something which he has overlooked being carried out. As an instance of what is meant, he might joint up the steam chest cover of a new steam engine, and forget to set the valves.

The author proposes in the following article to point out some of the duties which a millwright will be called upon to perform, and also to describe somewhat in detail the method of executing them. Whenever it is practicable, a mill is designed specially with a view to the class of machinery it is to accommodate, and the work it has to turn out, but it frequently happens that an existing building has to be used for an entirely different class of plant from that for which it was built. A very good method, and that adopted by the author, of setting out on a drawing the machinery of a mill, is to make little tracings, showing each machine in plan to the scale it is proposed to draw the general plan. These little plans can then be adjusted and re-adjusted until the arrangement is as nearly perfect as possible, when the leading points are pricked through to the general drawing and the details completed.

SETTING OUT.

Assuming that a millwright has been ordered to carry out all the mechanical work in connection with a new mill, he will, on his arrival, probably find chaos, no floors complete and everything wrong side up, so to speak. The first thing he should determine is a datum line from which to work, and the author considers that, for the purposes of a millwright, the floor level of the mill on which the machines are to stand is the simplest to work from. This line should be marked out on boards, firmly secured to the walls at intervals, and lines should be drawn across them, representing the thickness of the floor boards, and the depth of the joists.

If the main shaft is to be carried below the floor,—which is by far the best place for it, if the machines will drive from the underside,—a centre line must be laid down by driving stakes in the ground, or by nailing boards to the walls, marking the exact points with a notch, so that a line can be stretched the entire length, parallel with, or at right angles to, any existing wall or shafting. From this centre line the width of the excavations is staked out and the ground removed.

While the men are excavating this pit, the belt races to the machines should be marked out, so that they can be cut before the brickwork is commenced. It sometimes happens

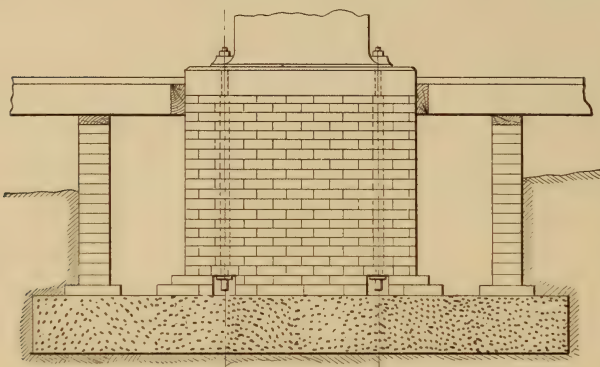


FIG I.

that, owing to bad ground, the excavations have to be carried to a greater depth than originally intended. This, however, makes no difference to the centre line of the shaft ; the only thing affected is the height in the pit of the piers which carry it.

When the excavating is finished, a layer of concrete (4 : 1) about 6 inches thick, should be laid over the entire width of the cutting, and when this is sufficiently set, the bricklayers can commence building the retaining walls and the piers for the shaft. If the depth below ground line, not floor line, exceeds 4 feet, it is better to make the lower portions of the retaining walls thicker, 9 inches doing very well to a depth of 4 feet, and 14 inches afterwards, unless very deep, when the thickness must be increased again.

All the brickwork below ground for the shafting should be set in cement, as this makes a much better job than mortar, although for light countershafts below the floor, mortar may be used in the piers. While the bricklayers are busy with the main shaft pit, the excavators can be cutting for the foundations of the various machines which are to stand on the ground floor of the mill. The positions of these are set out in the same manner as the shaft pit, but the centre lines are squared off the centre line of the main shaft.

Foundations.

The best foundations for machinery consist of brick in cement upon a bed of concrete resting on solid ground, the top of the brickwork being covered with a stone slab varying in thickness from 6 to 12 inches or more, according to the nature and size of the machine. Bolt holes, for holding-down bolts, which are left through the masonry are usually 3 inches square through the brickwork, and 2 inches in diameter through the stone. Stone slabs should be imbedded in the brickwork at the lower end of the bolt holes, to give a good bearing surface to the washer plates, which,

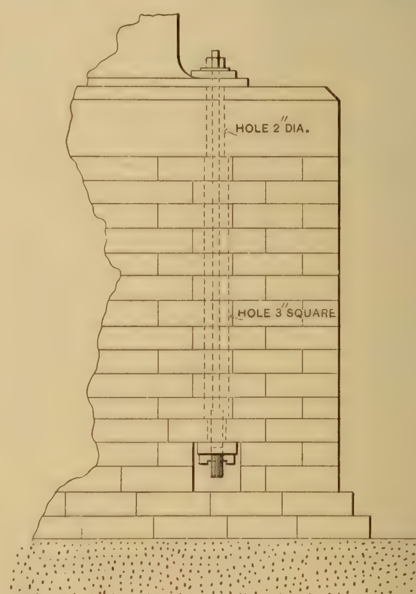


FIG. 2.

together with cotters, form the heads of the holding-down bolts. (See Figs. 1 and 2.)

Concrete foundations are frequently

used on account of their cheapness, and when properly made are really very good, care being taken to ensure that the Portland cement used is sound. Concrete foundations composed of 1 part of Portland cement to 4 parts of gravel will be found to be quite satisfactory. One of the drawbacks to concrete foundations, however, is the difficulty of leaving bolt holes in accurate positions. Iron or wood piping is built in, and the usual hand-hole is left for the bolt head down below, but great care will have to be taken to protect these pipes from displacement. When lewis bolts are used it is a very simple thing to put in a concrete foundation, and build in short pieces of wood which can easily be drawn when the concrete is set; but if a foundation is complicated, it is almost, if not quite, as cheap to build it of brick, as so much moulding of the concrete would materially increase the cost.

It is a great mistake to build bolts into concrete, for, when the cement has set, there is no moving them, and if they do not come right, it is a very troublesome job. It is also no easy matter to keep bolts true to ⅛ inch while a lot of labourers are shovelling in concrete. Bolt holes should always be left, although occasionally it may be necessary to put in a solid block of concrete and punch the holes afterwards, but this is a bad plan, as it both wastes time and tends to disintegrate the mass. Furthermore, it should be attempted only in the case of lewis bolts.

Wherever it is practicable, a clear passage should be left round foundations to enable a man to get up to the holding-down bolts. It also allows of the flooring being completed right up to the foundations before the machinery arrives, which, it may be mentioned, is no small consideration. (See Fig. 1.) Foundations should remain undisturbed until perfectly set.

Erection of Machinery.

The first and chief machine is the engine, which should be erected with the greatest possible care in every detail. When the engine foundation is set, the bed-plate of the engine is placed on it, and the holding-down bolts are passed through it, washers and nuts being put on, and the washer plates and cotters attached to the lower ends of them. The bed-plate is then levelled, iron strips or wedges being inserted between the casting and top of the stone where necessary. The holding-down bolts are then tightened slightly, and the whole of the underside of the bed-plate should be flooded with Portland cement grout, which should be allowed to set perfectly hard before any further work is done to the engine.

In the meantime, the main driving shaft, in the pit below the floor, has been got ready and the wall-plates on the shaft piers have been levelled, grouted up and firmly bolted down with through bolts. The plummer blocks

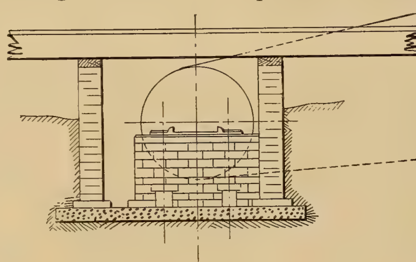


FIG. 3

are then placed on the wall plates and when both they and the shaft have been thoroughly cleaned, the latter is lifted into position and left until the crank shaft and fly-wheel of the engine are erected. Then the shaft is squared off them and the plummer blocks are bolted down firmly.

As regards pulleys on shafting, the author almost always prefers split ones, as they are so much more convenient, and are quite as cheap as solid cast ones. Wrought-iron split pulleys are also lighter and consequently there is not so much dead weight in the bearings.

In leaving belt races, it is desirable to have plenty of room both underneath the belt, to allow for the sagging, and at its sides, to allow of its being taken off and put on the pulley without jamming. Traps should be left in the floor to enable a man to get down to all the

main bearings, and the shaft piers should not extend the whole width of the shaft pit, but there should be sufficient space, about 12 to 15 inches at one side, to permit of a man passing without having to climb over, and also to enable the place to be more easily brushed out and kept clean. These openings should be on the side of the pit remote from the engine on account of the pull of the main driving belt (Fig. 3). One of the first things to do when erecting an engine or machine of considerable size, is to rig up a strong beam over it for purposes of lifting. This will be found extremely useful and will save much time. A good baulk of timber, about 12 inches square, will be found sufficient for almost anything, and should extend the whole length of the machine.

Location of Machines.

The location of machines requires much thought, the chief points being:—

1st. To get the machines absorbing most power near the engine.

2d. To ensure that each man working the machines shall have ample light.

3d. To so arrange the machines that the operators shall not be closer to each other than necessary, for if they are within talking distance, the output of work will not be as high as it would otherwise.

4th. To arrange machines so that the material passes from one to another without having to be carried unnecessary distances.

Of course it is almost impossible to have all these desirable conditions, but, with a little care and thought, many of them can be attained. Another important thing to locate, is the foreman's office, which should be well in sight of all the workmen and should have glass windows so arranged that he can see all over the shop.

Belting and Transmission of Power.

By far the most common system of transmitting power is by the leather or cotton belt, although, where long centres can be arranged between the pulleys, the author is rather favourably inclined towards rope driving, as a good rope drive runs so very smoothly, and, with care, will last almost as long as leather. The life of ropes is about 7 years, and the best speed for them to travel is between 4000 and 5000 feet per minute. Care should be taken that the pulleys are as large as possible in diameter, no pulley being less than 30 times the diameter of the rope, as the continual bending round a small pulley causes much internal friction, which is very detrimental. The size of rope usually adopted is 4¾ inches in circumference, which will allow a safe working strain of from 250 to 300 pounds. The cost of ropes, again, is in their favour, as it is only about ⅓ the amount that would be paid for leather.

The best lubricant for ropes is soft soap. The friction of a rope working in a taper groove on a cast-iron pulley is three times greater than that of a rope working on a cast iron pulley without a groove. The co-efficient of friction for a rope on a cast-iron pulley without a groove is 0.28, while that of a rope working in a taper groove on a cast-iron pulley is about 0.8 when the groove is not greased. If the groove be greased, the co-efficient of friction is reduced about one-half.

Rope gearing absorbs more power than toothed wheel gearing. The percentage of the total power developed by the engine expended in overcoming the friction of the engine, shafting and machinery in factories, averages about 25 per cent. when driven by toothed gearing, and 32 per cent. when driven by rope gearing. Of course, there are cases where ropes could not be used at all, as, for instance, where pulleys are close together, or where a fast and loose pulley have to be used.

Leather does not require such a large margin for sagging, which will be very considerable in the case of ropes, if the pulley centres are far apart and the lower rope is the slack one. Leather belting requires a good deal of care to work economically. When a belt begins to slip, it is usual to apply powdered rosin, but this is somewhat damaging

to the leather. A little printer's ink or currier's grease, is much better for it, the result obtained being the same and the belt remaining in better condition. Oil, too, is commonly used with rosin, which has the effect of causing the belt to rot and stretch. Belts should be cleaned and re-dressed about every four months, by sponging the dirt from them with warm water and soap, then drying with a cloth, and, while still damp, rubbing in currier's grease. When a belt has been allowed to become saturated with oil and breaks, as it will do when in that condition, it has the appearance of being burnt.

The ultimate strength of leather may be taken at about 3360 pounds per square inch of section, but as the strength of a belt is that of the joint, it is reduced to about 1320 pounds per square inch of section, and, allowing a factor of safety of ⅓, we get a working strength of about 440 pounds.

It would perhaps be well to mention, in connection with belting, one or two little things which probably are not well enough known. If a belt is required to do more work than was originally intended, say by an addition to the machinery in the mill, a very good plan is to place another belt over it, not connecting them in any way, and it will be found to do its own share of work. An experiment was made with four 6-inch single belts, running, one on top of the other, over 4-foot pulleys, and collectively they transmitted 80 H. P., the belts travelling at the rate of 1800 ft. per minute. Each of these belts did its own share of work, and while running over its own circumference, each gained a little over 30 ft. per minute upon the one below, so that the outside belt travelled over 90 ft. per minute faster than the inside one.

One of the most important things to ensure good running of belts, is to have absolute accuracy in the positions of the pulleys and shafts, which should be perfectly parallel with each other, for if the shafts be not parallel, then the pulley faces will not be so either, and the strap, with its natural tendency to find the highest point, will either rise until it slips off, or, if forks be used, there will be a continual rubbing against them, with much damage to the belt.

All belt pulleys should be rounded slightly towards the centre of the rim, except pulleys which drive on to fast and loose pulleys. The amount of convexity should be about ⅛ inch in 12 inches width, and for pulleys running at very high speeds and of small diameter the rounding should be double this. It is distinctly a bad practice to make pulleys with enormous convexity, as may be seen on some high speed machinery.

It has been asserted that belts running with the flesh side outwards will drive 30 per cent. more than in the ordinary way, but the author does not approve of the practice, as the inside of the belt would be considerably crushed,

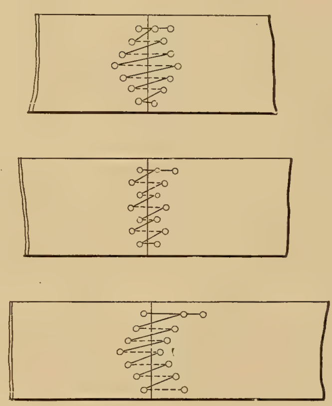


FIG. 4.

since the natural tendency of the leather to bend is in the other direction. An inexperienced millwright is very apt to pay too little attention to belting. He ought to know thoroughly how to put on, take up, and joint belts, but unless he understands his work he will almost invariably punch the holes for laces in parallel rows across the belt, whereas they should be punched in a diamond, or pointed form, as shown in Fig. 4, so that the belt section is not reduced unnecessarily at this, the weakest, point.

In punching a belt for lacing, it is de-

sirable to use an oval punch, the larger diameter of the punch being parallel with the belt, so as to cut out as little of the effective section as possible. All the lace holes should be properly marked out before commencing to punch them,

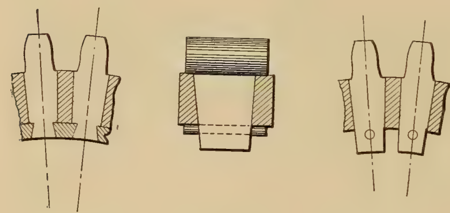


FIG. 5.

and in putting on a belt with a lapped joint, the joint should run with the pulleys and not against them.

Wheel Gearing.

There are several kinds of gearing, the most common being cog wheels parallel with, or at right angles to, each other. This kind of gearing is used when the wheel centres, being short, will not allow of a belt, where no slip between driver and driven is allowable, or where very great power is to be transmitted, as in the case of heavy rolls. The noise of gearing is rather objectionable, but this can be greatly reduced by forming the larger of the wheels with wooden teeth, made of horn beam, crabtree, beech, maple, iron wood, oak or other tough wood, driven into the mortises in the wheel rim and keyed on the other side (Fig. 5). No clearance need be left between the wooden teeth and the iron ones of the other wheel, the wood cogs being trimmed to fit accurately between them. When running at a high speed, mortise teeth are said to be as safe as iron teeth, but at low speed they are weaker.

Gear wheels should be well lubricated with wheel grease, which can be made with soft soap and plumbago, to reduce the friction of the teeth against each other and to reduce, also, the noise. The maximum working speed of toothed wheels, at the pitch line, in feet per minute, consistent with freedom from excessive wear and tear is,

For cast-iron wheels with straight teeth	1,800
" cast steel " " " "	2,100
" mortise wheels with wooden teeth	2,000
" cast-iron wheels with double helical teeth..	2, 00
" cast steel " " " " " ..	2,400
" worm wheels of iron or steel................	270

It might here be observed, in passing, that the head of key securing a bevel wheel to a shaft should be on the back of the wheel, so that the thrust of the fellow wheel forces it more securely on to the key (Fig. 6). The author cannot urge too strongly the necessity of keeping shafts parallel, or at the correct angle for toothed gearing, or else the teeth will get all the pressure on one corner, will work badly, and finally will break off, when repairs will become necessary with attendant delays. Teeth repairs are usually effected as shown in Fig. 7 on the opposite page.

The load which a tooth of a wheel will bear may be arrived at by considering the tooth as a cantilever, its length being that from root to point ; its depth, the thickness at the root, and its width, that of the wheel. A cantilever of good cast iron, 1 inch square and 1 inch long,

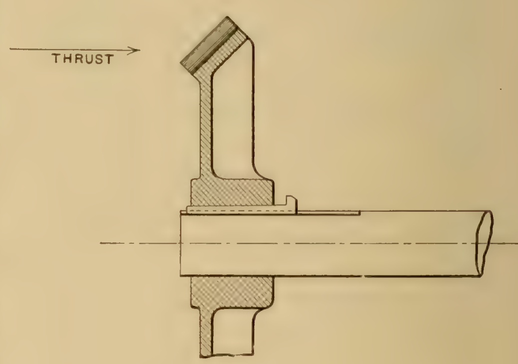


FIG. 6.

will sustain a dead load of 6000 pounds before rupture, but it is safer to estimate the strength of the tooth on the supposition that the load is concentrated at one corner. Properly formed teeth, however, as now produced, if accurately geared, may be assumed to work throughout their entire width, and, further, it may be assumed that two teeth are in contact at the same time,

thus reducing the strain by one-half on each tooth.

The ordinary method of increasing the strength of teeth of wheels is to carry a flange up to the pitch line of the teeth on both sides of the wheel. This is called shrouding, and increases the strength of the wheel from 40 per cent. to 50 per cent. This is shown in Fig. 8.

Bearings.

In passing on to bearings, it is of the utmost importance that the surface should be ample for the load it has to bear, and that there be not too great a distance between bearing centres. As regards bearing surface, the common rule is to make the length equal to two diameters, up to 3½ inches in diameter. When the diameter is greater than 3½ inches, this proportion is not main-

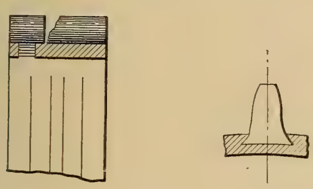


FIG. 7.

tained, but is reduced. Of course, these sizes refer only to bearings of ordinary line shafting and not to special bearings, such as those of engines or high speed journals. When designing main bearings, the author allows a pressure of from 400 to 600 pounds per square inch, measured by multiplying the diameter by the length, which, he has found, gives good results. It is somewhat lower than some engineers allow; but in actual work no trouble will be had, and bearings will be found to work without heating and with general economy.

When laying out the shafting arrangements of a mill, for shafting up to 3½ inches in diameter, the author uses the following rule for centre distances between bearings:—Multiply the diameter of the shaft in inches by 3, and call the result, feet. It is a simple rule, and unless the work to be taken off is unusually heavy, it is a good one to work to; but when the diameter of the shaft is 4 inches or more, the distance between the bearings is not so great. Where the main driving belts are taken off, it is usual to place a bearing close in on each side of the pulley, taking care to leave sufficient room between them for putting on the belt.

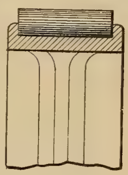


FIG. 8.

The lubrication of bearings is a subject which ought not to be omitted in a paper of this kind, but as there is matter enough in this for a long paper, the author can only briefly mention a few points, gleaned from practical experience. In starting a new mill, it is usual to hear of hot bearings at different points, notwithstanding the care taken during erection, and in such cases a little castor oil and white lead, mixed into a thick cream, will be found to be a very efficient lubricant, the castor oil having sufficient viscosity at a somewhat high temperature to remain in the bearing, and the white lead forming a good body between the two rubbing surfaces.

It is important to use oil having a high flashing point in mills where inflammable material is being worked, as the heat generated by a bad bearing is occasionally sufficient to set fire to the oil. The best lubricant for general work is that which has a high specific gravity and good viscosity at high temperatures, but this, again, greatly depends upon the class of machinery which is at work. For instance, light-running machinery is well cared for by sperm oil; heavy machinery, by rape oil; while olive oil does for almost any kind of machinery, excepting steam cylinders and slides, in which places it has not sufficient body owing to the heat, whereas neatsfoot oil and tallow or heavy mineral oil answer very well. There are now on the market some lubricating greases, of which the chief function is to melt freely by the heat generated by friction, and so supply more lubricant; but, although they may be good in certain places, the author does not like them for general use, as they depend for their action

upon the very thing that they are intended to reduce, namely, frictional heat.

When erecting a line of shafting either underground or overhead, the first thing to do is to fix either a plummer block, wall plate or bracket, as the case may be, and level up to the next one from it, and so travel the entire length; but to ensure the bearings being in line the author prefers a thin steel wire, stretched the entire length as tightly as possible. To this line the bearings can be set with great nicety, so that, when the shaft is lifted into position, there will be no adjusting necessary. A piece of hard wood should also be inserted between the foot of the plummer blocks and the

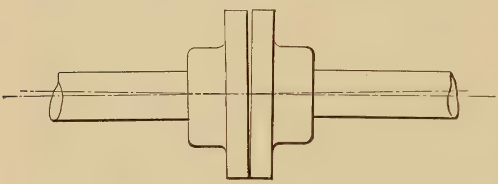


FIG. 9.

wall brackets or plates, in order that a more even bearing may be obtained and to enable the bolts to take a firmer hold.

If the accuracy of a line of shafting be at any time doubted, the coupling bolts should be drawn, when, if the shaft be not truly in line, a wedge-shaped opening will appear between the faces, as shown in Fig. 9.

Lifting Heavy Weights.

The subject of lifting is of such a varied character that the author cannot do more than explain broadly the principles of lifting and moving heavy weights from a practical point of view. The best appliance, undoubtedly, is an overhead crane, but as this is a luxury seldom, if ever, to be found in a new mill, all lifting has to be done by temporary tackle.

Assuming that a truck has just arrived with a heavy machine, the question arises, how to get it out? If several machines were coming, the best arrangement would be to rig up a lifting tackle, under which the trucks can be run. This tackle may be of any description, the most common being shear legs. If a single lift is all that is required, then a derrick may be upended and guyed, care being taken to incline it as little as possible. A common method of strengthening a derrick is to lash 3 or 4 poles together, which will be found to answer the purpose almost as well as one large one. Another way of getting a heavy weight from a truck, is to erect a few planks at the same height as the truck bottom, and roll the weight on to them. Then the truck can be moved off, and the weight lowered gradually, one end at a time, by jacks or pinch bars.

The author well remembers an incident which occurred while erecting machinery in Liverpool. A case, containing a machine weighing some tons, was being brought along in a low truck over soft ground, when suddenly the wheels of the truck sunk to their hubs and the bottom rested on the earth. The case could not be moved by hand, no lifting tackle was available, and, owing to its being confined on three sides by the truck, only one roller could be got under it at the front end. Two jacks were obtained and got to work in the back of the truck, and a strong horse was harnessed to the case. All the available force was thus brought to bear on the case, which rolled out of the truck on to timbers placed to receive it. The rest of the journey, fortunately not very far, was performed on rollers.

When it is required to lift a weight and place it in another spot, no travelling crane being at hand, a block and tackle should be erected over the weight, and another over the new spot; the first tackle then lifts while the second pulls over; the first then pays out, and second lowers into new position (Fig. 10).

Great care should be taken of lifting-slings, so that they be not damaged, a sack being placed over any sharp edge against which the sling binds. The author prefers rope slings to chain ones for general work, as they are more

likely to give warning in case of breakage than chain. A sudden sag in a chain carrying a weight frequently snaps it, while a rope would give. As a rule, new white ropes are stronger

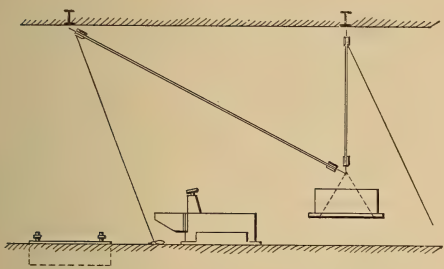


FIG. 10.

and more pliable than tarred ones. The tarred rope, however, retains its original strength for a longer period, especially when exposed to wet. The ultimate strength of ropes is usually considered to be about 6400 pounds per square inch of sectional area.

There is a great loss of strength from exposure, wear and tear, during a few months of working, the loss varying from 20 per cent. to 50 per cent.; therefore, a large margin should always be left for safety, about 1-5 the ultimate strength being the usual load. A still further allowance should be made in the case of a sling passing over a crane hook, which causes a sharp bend, the strength of a double sling in this case being only about 1¾ times that of the single; but if the rope passes over pulleys, its full strength would be retained.

Staging.

It frequently happens that a millwright has to direct his men to put up a staging to enable him to erect plant at a considerable height above ground, but as the form which this will assume will be entirely governed by local circumstances, it is impossible to give any detailed explanation concerning it. The best men to do this work, however, are sailors, if they can be obtained, and if the work be of sufficient importance, to have men for this job. Fig 11 shows the most common methods in use.

Chimneys and Boilers.

When designing a mill, care should be taken to have boilers and engines in a convenient and accessible place, so that coal and stores may be brought in without much trouble. It should, likewise, not be forgotten to leave space enough for drawing the boilers when new ones are required. It is usual to rest boilers on fire brick set in fire clay, but the author prefers cast-iron standards, when they can be used, to take the weight of the boiler.

The outside diameter at the base of a brick chimney should not be less than one-tenth the height, and the thickness of material in the sides of the chimney should be 9 inches for the top 20 feet, and 14, 18, 24, 27 and 31½ inches, respectively, for the lower 20-foot lengths. The batter should be 2⅝ to 3 inches

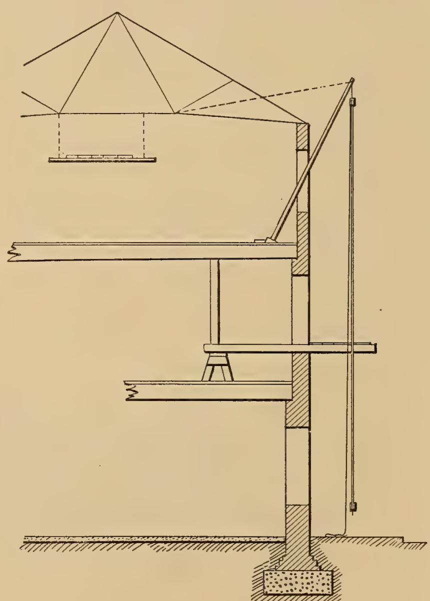


FIG. 11.

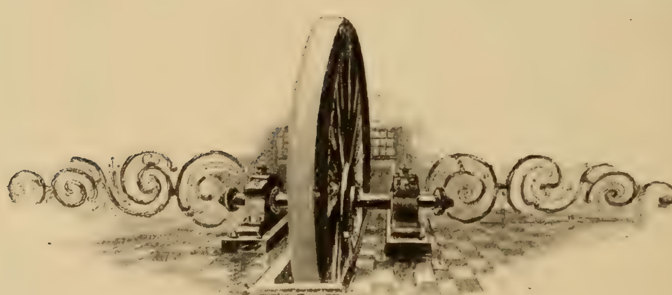
in 10 feet. The top cap is preferably of cast iron, although stone is frequently used, and the firebrick lining, one or one and a half bricks thick, should be carried up at least 20 feet, with an air space 4½ inches wide between it and the outer brickwork. The bottom of the chimney should be closed

by an invert, not less than 14 inches in thickness, depending on height and weight.

Long horizontal flues should be avoided as much as possible, as they tend to lessen the draught, and their area should be greater than that of the chimney. The use of internal scaffolding when erecting brick chimneys will be found very convenient, if the size of chimney will permit of it, as it is much cheaper than external, and is much safer for the men. A small winch can be used for hoisting materials up the centre, and the permanent iron ladder, which should always be on the inside of every chimney, can be used during its erection.

An iron chimney can be very easily erected by means of a tall and strong derrick, which will lift it about the centre of its length. Ropes and tackle can be secured to the lower end of the chimney to pull it into position ; but be sure everything is sound and strong before attempting to do a job of this kind, and also see that the chimney cannot slip through its sling. Lastly, do not forget to put on the chimney guy ropes before you commence lifting.

There are many things left unsaid and many things which can be learned only by experience. Almost every item, briefly touched upon in the foregoing paper, could be enlarged to occupy several pages. There is always a sense of satisfaction in having executed work with only the very crudest of tackle, such as is to be found in new countries. Residence for some years abroad has taught the author how to dispense with many of the appliances which are considered absolutely necessary at home, and he has more than once been convinced of the truth of the old saying, "Where there's a will there's a way."



CHEAP GAS POWER.

B. H. Thwaite, C. E.

THE law of the survival of the fittest, under the influence of the fierce struggles associated with modern industrial warfare, is forcing the governing heads of the great manufacturing concerns to search for the cheapest and best means of generating the motive power essential to the running of machinery. The corn millers of the last and the preceding centuries located their mills alongside a stream or on the summit of a hill, so that the water-fall in one instance and the winds in the other, supplied the power required and under the most favourable economic conditions in proportion to the limited output of these picturesque factories.

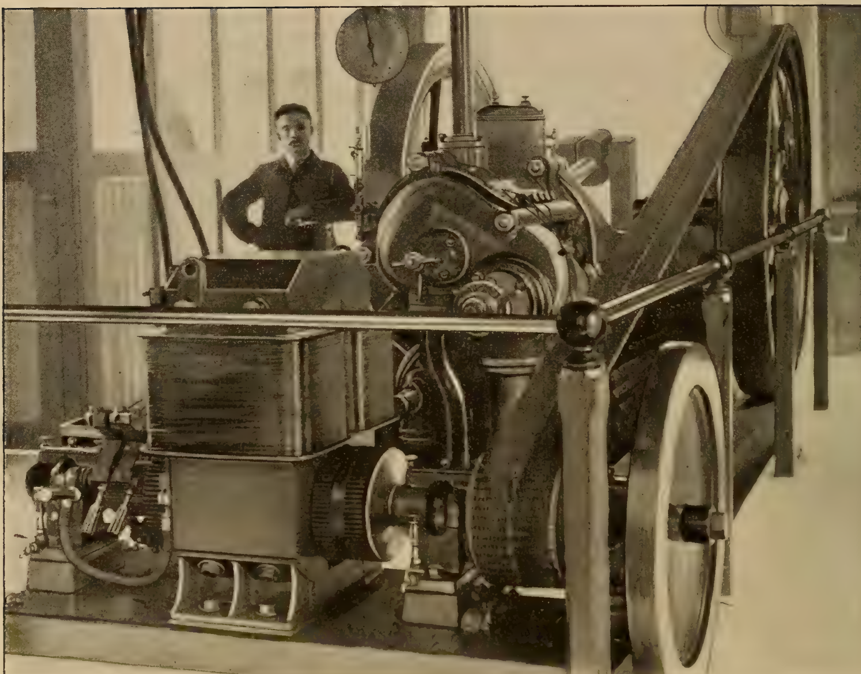
The metamorphosis in our industrial methods, involving an increase of output measured in thousand folds, called for the displacement of the water-wheel and wind-mill by apparatus that enabled the conversion of the heat stored up in fuel, into dynamic energy or motive power, and the choice of the location of a great manufactory was more or less influenced by proximity to a navigable waterway or railway by which the fuel could be easily and economically obtained.

Immense manufactories, surrounded by well populated townships, whose inhabitants depend upon the staple industries carried on, have resulted from the application of fuel as a means of obtaining unlimited power production, and yet industrial concerns will, in the near future, have to be carried on more or less in the face of competition with modern types of water-propelled or turbine machinery, from which dynamic energy may be electrically transmitted under ideal arrangements for acquiring the highest efficiency. The initiation of this new water and electric power in Switzerland, France, Germany and at Niagara, in the United States, represents another phase in industrial history, the immense influence of which it is impossible to forecast.

In one direction, its influence will be welcomed by thermo-dynamists. This harnessing of the power of gravity of falling water by that masterpiece of practical mathematics, the turbine, will compel the users of fuel-driven machinery to adopt thermo-dynamic means of power production that will leave the least margin in favour of waterfall power. That the margin is intrinsically of serious proportions will be evident to the most casual observer who examines the following side-by-side comparison of the labour and essentials required for the production of power, by the two sytems.

WATER FALL POWER.	FUEL POWER.
Water Fall, Water Conduits.	Coal Mine or Pit.
Turbine Tunnel or Shaft.	Coal Cutting and Hoisting Machinery.
Turbine.	Railway and Cartage.
Electrical Conversion and Energy Transmission Plant.	Coal Depots.
	SteamBoiler and Chimney.
	Steam Engine and Condenser.
	Gearing and Shafting
	Power Transmission Arrangements.

There is quite as great a disparity in the labour requirements of the two systems, and the charges of maintenance, plus the charges for boiler insurance, associated with steam plant, have no equivalent counterpart in the turbine practice. That the competition of this scientific utilisation of the force of falling water will accelerate the prog-



AN ECONOMIC POWER GAS ENGINE AND ELECTRIC PLANT, DRIVEN BY CHEAP GAS.

ress of the displacement of the steam power system for land use, is certain. A system of power production that involves so many sources of waste, as does a steam power plant, cannot long survive in the race for supremacy with the turbine as a rival. The steam power invention, although a glorious victory for science and a great honour to Watt and his illustrious contemporaries, Papin and others, cannot be considered, except in its application for marine purposes, to be worthy of our existing knowledge of practical thermo-dynamics.

Thanks to the genius of Otto, of Lenoir, and of their co-workers, we have another instrument by which the power potential of our fuel can be recovered for thermo-dynamic use and with incomparably greater efficiency than is obtained from steam engines of even the highest excellence of design and workmanship. The theoretic efficiency of the latter is only about equal to the practical efficiency of the gas engine.

Let us broadly compare the different phases of the two systems of converting the heat potential of fuel into motive power or dynamic energy. The gas engine in this comparison is assumed to be driven with generator gas, for which one-fourth of the heat value is taken as being absorbed in the work of fuel gasification. Let x represent the combustible value of the fuel.

STEAM PLANT TYPE.	GAS POWER TYPE.
x Burnt in steam boiler.	$\frac{1}{4}x$ Absorbed gasification.
$\frac{1}{3}x$ Lost in radiation and chimney gases.	$\frac{3}{4}x$ Is carried and supplied to engine, of which by direct conversion 1-5 may be taken to represent the degree of thermo-dynamic conversion. Therefore, the efficiency of the gas engine may be taken to equal $\frac{(\frac{3}{4}x)}{5}$.
$\frac{2}{3}x$ Carried forward to steam engine and of this $\frac{2}{3}x$, one-tenth may be taken to represent the proportion of the heat value converted into dynamic energy or motive power. Therefore, the efficiency of the steam engine equals $\frac{(\frac{2}{3}x)}{10}$.	
Equivalent to 6.6 per cent. efficiency.	Equivalent to 15 per cent. efficiency.

The heat loss (represented by $\frac{1}{4}x$) involved in thermo-chemical work of gasification will be very much reduced in large installations. In these, part of the heat carried from the gas generator in a sensible form, will be recovered for gasification work, and part of the heat of the cylinder jacket water will also be utilised for the same purpose, so that the superior efficiency of the gas engine will be further augmented.

In the gas engine three-fourths of the combustible value of the fuel is secured

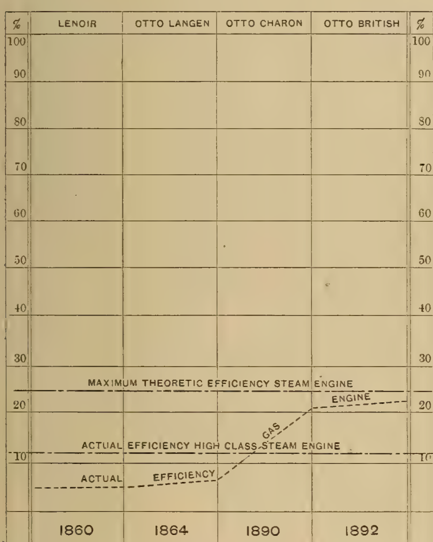


DIAGRAM OF GAS ENGINE EFFICIENCIES.

in the cylinder for direct conversion into power under the most perfect conditions of combustion.

In the steam plant, this fuel is burnt, under the worst possible conditions, in the furnaces of a steam boiler, and from the author's own experience, he avers that this fuel, burnt in steam boilers of the best design, never gives out more than 9-13 of its actual evaporative value. Certain data giving evaporative results have been published by well known engineering professors, giving much higher evaporative values than this 9-13 factor, but the author refuses to accept these higher results as close reflections of the actual work of evaporation, accomplished in day-by-day, useful work.

A test of a steam power plant should be of at least 8 hours' duration; one of a shorter period is worse than useless, as it is likely to give results that are misleading. The author ventures to throw out a suggestion to the effect that every government having any pretensions to industrial greatness should institute a committee of experts to carry out official tests of new improvements and inventions relating to engineering, and an international congress of experts should arrange a standard by which all the tests should be regulated. The ordinary power user would soon learn to insist upon tests by this officially appointed committee, whose members should be precluded from testing or reporting unofficially. This is a digression, prompted by a knowledge of the misleading character of many of the reports of evaporation tests.

The factor 9-13, noted above, is sometimes seriously reduced by steam pipe condensation. Few, perhaps, realise the extent of the loss in long lengths of steam pipes, especially if exposed to open air influences. This fact gives electrical transmission methods an unapproachable advantage. In the burning of hydro-carbonaceous fuel in furnaces of steam boilers, the greater part of the hydro-carbons, owing to the high volatility and the irrational combustion arrangements, escape unburnt, and as certain coals contain a considerable proportion of these hydrocarbons, the loss is occasionally very material.

In a power gas plant, on the other hand, most of the combustible constituents of the hydro-carbon series are utilised, either in the form of heat assets, convertible into power, or in the form of pitch or tar, both of which are saleable residuals. For large power installations, and it may at once be said that these will be necessary to place fuel power users on the same plane of advantage with those employing water power, the power gas plant offers still further economical advantages, permitting the recovery of the

A POWER GAS GENERATING PLANT.

nitrogenous constituents as well as the pitch and tar already mentioned.

It may be argued that these advantages could be obtained by converting the fuel into combustible gas and burning this gas in steam boilers. This will be conceded, but the author's own experience has satisfied him that the combustion of gas is not by any means effected under the best conditions in a boiler furnace, and that no man in his senses, having gone so far as to put down a gas plant, would do other than burn this gas directly inside the cylinder of a thermo-dynamic motor or gas engine itself.

In a large power gas installation, the putting down of a sulphate of ammonia (nitrogenous recovery) and pitch and tar plant, using an average hydro

carbonaceous fuel, would enable the following results to be obtained. An experience of such a recovery in England has shown an average production of about 17 or 18 pounds of sulphate of ammonia per ton of fuel burnt, the marketable value of which in England varies between £10 and £10½ per ton. Ammonia sulphate is a most valuable fertiliser, and the return of this nitrogenous agent to the earth fulfills, in a natural order, the cycle of the conservation of energy.

Besides the fertiliser, an amount of pitch, equal to 0.062 tons, is obtained from each ton of coal charged into the gas generator. This pitch is worth from 20/– to 25/– per ton. In addition, from 5½ to 6 gallons of oil are recovered per ton of coal used, and this realises from 1¼d. to 1¾d. a gallon. The net profit, after deducting all charges, will vary between 2/6 to 3/– a ton, depending upon the market value of the three residuals.

For large power installations, the cost in coal consumption with a gas power plant should not exceed 1¼ lb. per kilowatt-hour, and if we take the cost of coal fuel to be 12/– a ton, the monetary cost of the fuel per kilowatt-hour, after deducting the profit value of the residuals, will be 0.0602 pence.

Compared with the monetary value of fuel equal to 0.144 pence per kilowatt-hour, representing the best work of a triple-expansion steam engine, the steam power plant is conspicuously more costly. It may be, therefore, well claimed that the cheapest coal fuel power plant is one that includes a gas plant, a nitrogenous recovery installation and a suitable Otto-cycle gas engine. If the power plant were installed on the coal field, it is quite possible that the value of the recovered agents would be equal to half the cost of the fuel.

The entire absence, in gas power installations, of high-pressure retaining vessels, removes the possibility of explosive dangers, and the associated insurance costs are therefore unnecessary. The absence of any considerable demand for water, and the comparative independence of its quality of purity and hardness, are advantages that will be appreciated by power users. Then the absence of that curse of steam plant engineering system, the smoky chimney, is something for which to be thankful.

The economic quality possessed in such a high degree by the gas-power system is amplified by the advantages of convenience, and the absence of the explosive associates of steam boilers will remove one of the sources of worry that accompanies the daily cares of steam-power users. Therefore, in comparison with water power which we will place in the first position, and where solid coal is the only fuel available, the gas-power system takes precedence of the steam plant, and this decision is amply confirmed when the respective merits are measured by the equation of efficiency which we owe to that illustrious engineer, Sadi Carnot.

If, in the natural gas districts, the gas were available at a price that would compare with generator gas on a heat valuation basis—then a natural gas-power plant would, obviously, be superior to a generator gas plant, although for such an installation it would be advisable to have an auxiliary generator plant as a stand-by.

There is very little probability that oil engines will ever be able to seriously compete with large gas-power plants. The limited proprietorship and insignificance of the weight output of the oil fields are facts too potent to prevent large competition against coal generator plants.

For municipal purposes, use may be made of the organic and other combustible refuse of towns for generating power, but to a very contracted extent. The heating value of this refuse fuel has been very much over-valued. When it is known that the vegetable organic matter that enters so largely into the constitution of town refuse, contains from 50 to 80 per cent. of moisture, it requires no lengthy explanation to show that before any heat energy is available for useful external evaporation work, a considerable proportion of,

if not all, the heat available in the burning of the solid portion of the organic matter is absorbed in the internal work of evaporating this moisture. It is difficult to estimate the calorific or heating value of this refuse fuel, as every town will have its own characteristic kind of refuse. The author, some years ago, prepared a guiding equation which makes out that with good average refuse, an evaporative value not exceeding one-fifth of that of ordinary common coal might be taken.

The low heating value necessarily involves a large expenditure in steam generation plant, to obtain equivalent power output. But even allowing for this fact, involving high prime cost of steam boiler plant, it is conceivable under certain circumstances that for limited municipal purposes, this refuse fuel may be economically employed ; but it can never, except to a very insignificant extent, come into commercial competition with the use of coal.

A central, coal field gas-power installation on the lines outlined in the foregoing pages will permit dynamic energy to be produced for transmission by high-pressure, alternating electric currents, to distances up to 100 miles, at a cost, if we assume the employment of approved electrical methods of driving manufactories, that would bring this energy well within the limit prescribed by the expression, cheap power.

ELECTRIC VS. STEAM HEATING.

By A. F. Nagle.

WHILE electrical appliances of every kind are vigorously pushed upon the market, none are looked upon by the public with more favour than those designed for electric heating. They are simple and neat in construction ; perfectly free from dust, smoke or ashes ; and are easily managed, requiring no skill or special training or fitness for the work; in fact, a child can manage them. Altogether the electric system is an ideal one of heating, except for one thing,—its cost. There may be circumstances where cost cuts no figure, or where some of the advantages above enumerated outweigh it, but in either case, it may be well to know what the cost of electrical heating really is as compared with steam heating, and this inquiry is instituted for that purpose.

Steam is generated at greatly varying cost. Steam plants themselves vary in first cost, and the subsequent cost of evaporating water is considerably affected thereby. But more than the plants themselves vary the costs of fuels. Coal as low as $1 a ton, and as high as $5 (from 4 to 20 sh.) is used for making steam, and it is a singular fact that the price of coal is rarely based upon its evaporating, or steam-making, qualities. The cheapest coal will evaporate, in good furnaces, more than one-half as much water as the very best coal costing five and six times as much ; and a good, yet cheap, coal will evaporate 75 per cent. as much water as a somewhat better coal costing two or three times as much. This is owing to the difficulty of burning the very cheap coal free from excessive smoke. There is no doubt that as soon as it becomes known how to burn cheap coal, dust and screenings quite successfully—and it can be done—the price will approximate to its evaporative power.

From this statement of the cost and qualities of different coals, it is evident that in making an estimate of the comparative costs of steam and electric heating, some fixed basis must be taken. The price of coal can be left out of this calculation entirely, but a

definite evaporative quality can be assumed, and subsequent corrections can be made when applied to any particular case. We will therefore assume that steam is being generated at the rate of 10 lbs. of water per pound of coal. It is understood by professional engineers that this means from and at 212 degrees,—that is, 9657 British thermal units are being obtained from each pound of coal burned. These 9657 heat units represent the latent heat of steam, or the amount of heat necessary to change water into steam,—a liquid into a vapour.

A steam-heating system can be constructed where nearly every unit of heat as above assumed can be utilised. Its efficiency in that case would be 100 per cent. This is found in direct return heating systems. In a large building, where the main supply pipes are very long, but well covered with a good non-conducting material, the waste heat should not exceed 10 per cent., and there an efficiency of 90 per cent. can be realised. Sometimes it is not possible to save the condensed steam. In that case the entire waste might amount to 25 per cent., or an efficiency of only 75 per cent. might be obtained; but this would be decidedly the worst case of steam heating.

Now let us look at the process followed in electric heating. Practically, we begin with the same steam that is used in steam heating, except that it is of a higher pressure. This steam passes through a steam engine, and a small part of its heat is converted (transmuted, is perhaps a better word) into mechanical motion, and the larger part is wasted either into the atmosphere or into a condenser. This larger waste is unavoidable, because it is the heat necessary to maintain itself as a vapour in passing from a liquid to a gaseous state. The amount of this waste may be reduced by skillful designs, but it can never be entirely avoided. Just what this waste amounts to under certain conditions will be investigated later.

The mechanical motion of the engine gives motion to an electric generator, thus producing electricity, and the latter is carried by conductors to the place where heat is to be used, being there converted into heat by means of electric heaters. These perform precisely the same function as steam radiators. It makes no difference how the heat is obtained, whether from steam, hot water, hot air, electricity, or fire,—to produce equally good results, the same quantity of heat, or number of British thermal units, must be supplied in each case.

The electric heater is nothing more than a resistance box,—a device which wastes electric power by converting it into heat, just as one might waste his own muscular power by rubbing his hands together and thereby convert muscular power into heat. The resistance, or friction, which the electric current meets in passing through this resistance box, converts its power into heat. This process is a very perfect one, in fact, absolutely perfect, because all of the power is converted into heat, hence its efficiency is 100 per cent. To bring the electricity from a central station to the house, or railroad train, to be heated will entail a loss, depending upon the length and size of wire used, but 5 per cent. loss is a fair one to be taken, so that, the efficiency of the line being 95 per cent., the combined efficiency of line and heater remains 95 per cent.

The electric generator is a machine which converts the mechanical power of the engine into electricity. In skillfully designed generators this transformation is effected very efficiently. As high as 97 per cent. is at times obtained, but 92 per cent. is a very common result under good conditions, while it runs down to 80 per cent. and less, under less favourable conditions. Perhaps 90 per cent. efficiency would be a fair average under good conditions, making the combined efficiency of heater, line and generator equal to 85.5 per cent.

The steam which gives motion to an engine, and indirectly to a generator, has also to overcome the mechanical friction of the engine. This friction is about 10 per cent., so that only 90 per cent. is available for driving the electric

generator. When we say then that the engine has a mechanical efficiency of 90 per cent., the entire efficiency of the mechanism, from the engine to the heater, is only 77 per cent.

We will now investigate the efficiency of the steam supplied to the engine as a motive power. Correctly speaking, electricity is not a motive power; it is not a prime, or first, mover. It only conveys power given to it from some other source. Electricity, once generated, does its future work very economically—far more economically than steam ; but the difficulty is to generate it economically. Thus far, no way has been found to generate it more economically than is now done by mechanical power.

In the case of steam engines used for electric station work we need consider only those of a fairly economical type. It is customary to speak of steam engine economy by the number of pounds of feed water (steam) they consume per indicated horse-power (I. H. P.) per hour. The very best steam engines consume about 12 lbs. of water per I. H. P. per hour, and from this they range up to 20 lbs. and 24 lbs. There another type steps in which consumes from 25 lbs. to 35 lbs. and 40 lbs. But for the purposes of this inquiry we will take a good, modern, compound condensing engine, consuming say 18 lbs. of feed water per I. H. P. per hour. What is the efficiency of such an engine ?

By efficiency in this connection is meant the ratio of the heat contained in the steam, which goes to make the power of the steam engine, to the total heat it contained before it went to the engine. We must put figures to these expressions. A pound of water, of say 100 degrees temperature, turned into steam of 125 lbs. pressure, contains 1,090 units of heat (B. T. U.). We have assumed that 18 lbs. of water would be consumed in producing one horse-power in the engine. Then 19,620 B. T. U. would be required to develop one mechanical horse-power for an hour. It is commonly known that a horse-power is the expression for the mechanical work of 33,000 foot-pounds per minute, or 1,980,000 foot-pounds per hour.

Science has taught us that mechanical work and heat are convertible, one into the other, in the proportion of 772 foot-pounds of work to 1 unit of heat (B. T. U.). This figure is found by a simple experiment. If a paddle wheel be submerged in a vessel of water well protected against being heated or cooled by outside influences, and rotated, the agitation, or friction, of the water will warm it. Just as rubbing two solid bodies together will cause them to heat, so will fluids be heated by agitation, or friction, of their particles. If a crank, turning this paddle wheel, have applied to it 1 lb. pressure, and describe say one foot in one revolution, then when it has made 772 revolutions it will be found that it has heated the water one degree on the Fahrenheit thermometer, providing there were just one pound of water in the vessel. If there were 10 lbs. then the rise in temperature would be one-tenth of a degree, and so on. This experiment has been made many times with great care, and it is finally settled among scientific men that 772 foot-pounds of work are the exact equivalent of one unit of heat. A mechanical horse-power per hour,—1,980,000 foot-pounds,—is therefore equivalent to 2565 B. T. U. We have seen that the 18 lbs. of steam, furnished to the engine, contained 19,620 B. T. U. for each horse-power developed ; hence the efficiency of this engine is expressed by the ratio of 2565 to 19,620, which is 13 per cent.

Finally, to obtain the efficiency of the entire electric heating system, we must multiply the electrical and mechanical efficiencies already obtained, namely, 77 per cent., by the steam efficiency just found (13 per cent.) and we have an ultimate efficiency of only 10 per cent. The foregoing calculations have been based upon steam consumption. Let us carry it a little further and see what the efficiency would be if based upon coal consumption.

In the case of steam heating, we

assumed an evaporation of 10 lbs. of water, from and at 212 degrees, per pound of coal. Each pound of this steam contains and gives up 966 units of heat. In the case of the steam furnished to the engine at 125 lbs. pressure, we found that each pound of steam contained 1090 units of heat, so that for each pound of steam used in the engine 13 per cent. more heat had to be supplied by the coal than in case the steam were used directly for steam heating. That is, instead of getting an efficiency of 10 per cent., if based upon equal weights of steam used, regardless of the amount of heat contained in the steam, and if correction be made, as properly it should be, for the difference in the amounts of heat contained in the steam used in the two cases, an efficiency of only 8.85 per cent. would finally be realised, or, fully above eleven times as much coal would be necessary to heat by electricity than by a simple system of direct steam heating.

We have now a constant, expressing the economic ratio between electric and steam heating. We have given the data upon which this constant is founded. Should other data be assumed, or known to exist in any practical case, a new value could readily be found by simple substitution of other data. If, for example, the engine required 24 lbs. of steam per I. H. P. per hour instead of 18 lbs., then the efficiency would be only 6.63 per cent., or, 15 times as much coal would be required for electric heating as for steam heating.

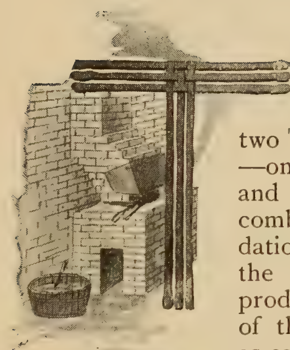
If, on the other hand, steam heating were obtained with an evaporation of only 7 lbs. of water, instead of 10 lbs. and the engine still required only 18 lbs. of feed water per I. H. P. per hour then the ratio of electric to steam economy would be increased from 8.5 per cent. to 12.64 per cent ; or, eight times as much coal would still be required for electric heating as for steam heating. We may take this last case as representing, fairly, the relative economy of steam in a large plant, and a small house heating system, but with this difference that the cost of coal used in house heating would be about $5 (20 sh.) per ton, while the coal for the electric plant would cost only about $1.25 (5 sh.) per ton, making the relative cost in money for fuel consumption only 2 to 1, instead of 8 to 1, as previously found in weight of coal used. That is to say, taking a first-class, modern, electric generating plant, using cheap coal, and an ordinary house steam-heating system using hard, or anthracite coal, and leaving out of consideration the value of the investments, cost of operating and other necessary expenses, but considering only the cost of coal in the two cases, electric heating will still cost twice as much as steam heating. Summing up briefly, we have the following :—

RELATIVE COST OF ELECTRIC AND STEAM HEATING.

	Electric.		Steam.
For equal weights of feed water...	10	to	1
For equal weights of coal..........	11	to	1
For equal cost of coal under extreme and most favourable conditions...	2	to	1

GASEOUS FUELS.

By H. L. Gantt, A. B., M. E.



THE fact that carbon forms with oxygen two gaseous compounds, —one by its incomplete, and one by its complete combustion,—is the foundation on which is based the manufacture of all producer gas. The first of these gases is known as carbonic oxide (C O), and in its formation thirty per cent. of the heating power of the carbon is developed, leaving seventy per cent. to be developed on its further combustion to carbonic acid ($C\ O_2$).

The carbonic oxide is, of course, very hot, and if burned at once to carbonic acid and the heat utilised, there would be no waste ; but if the gas should be conveyed any distance the sensible heat, amounting to thirty per cent. of the whole, would be lost by radiation. If it is desirable to utilise the gas at a distance from the point at which it is generated, it should have, on leaving the producer, as low a temperature as possible, the loss from radiation being thus lessened.

The fact that incandescent carbon decomposes water, taking to itself the oxygen to form carbonic oxide, and setting free the hydrogen, and in this operation absorbs a large quantity of heat, now comes to our aid. If the carbon be burned with a mixture of oxygen and steam, we have formed a gas much lower in temperature, but containing, besides the carbonic oxide, a certain amount of hydrogen, the loss of sensible heat being made good by its higher calorific value. This would be what is known as water-gas, but what obtains in practice, while based on the same properties of carbon, oxygen and hydrogen, is much more complicated.

First, in place of carbon we have coal, which contains, besides carbon, volatile hydrocarbons and ash. Then we do not use oxygen, but air,—a mixture of oxygen and nitrogen ; and lastly, we cannot convert all the carbon into carbonic oxide without converting a portion of it into carbonic acid. The result of this is that producer gas consists of carbonic oxide, carbonic acid, hydrogen, hydrocarbons and nitrogen, the combustible portion of the mixture being usually considerably less than 50 per cent. The fact that it is so poor in combustible, and consequently low in calorific power, is a great drawback to its extended use ; but for a number of purposes it has become the standard fuel, and its use is rapidly growing.

Before going more into the details of what goes on in the gas producer, it will be well for us to understand more thoroughly the substances with which we have to deal. Air, by weight, contains 23 parts of oxygen (O) and 77 parts of nitrogen (N). Air, by volume, contains 21 parts of oxygen (O) and 79 parts of nitrogen (N). One pound of carbon, burned to carbonic oxide, consumes 1.33 pounds of oxygen, which carries with it 4.46 pounds of nitrogen, making, in all, 6.79 pounds of gas, of which 2.33 pounds are carbonic oxide. One pound of carbon, burned to carbonic acid ($C\ O_2$), consumes 2.667 pounds of oxygen, which carries with it 8.927 pounds of nitrogen, making the products of combustion, in all, amount to 12.594 pounds.

In the following table will be found the calorific power of the various substances to be dealt with, expressed in British thermal units (B. T. U.). For

the information of those who may not remember exactly what a British thermal unit is, I may state that it is the amount of heat required to raise one pound of water through 1° Fahrenheit.

Heat Units Developed in Burning.	B. T. U. for 1 pound of combustible.	B. T. U. for 1 cu. ft. of combustible.
C to CO	4,400	----
C to CO_2	14,500	----
CO to CO_2	4,325	319.
H to H_2O	62,000	327.
CH_4 to CO_2 and H_2O	23,500	1007.
C_2H_2 to CO_2 and H_2O	21,400	1593.

The heat energies are calculated upon the assumption that 62° F. is the initial temperature, and that the products of combustion are reduced to that temperature.

To further facilitate our calculation, the following table gives the number of cubic feet in one pound of the following gases at 62° F. and at atmospheric pressure :

Volume in Cubic Feet at One Pound at 62° F. and Atmospheric Pressure.

Air	----	13.14	Cubic feet.
Nitrogen	N	13.50	"
Oxygen	O	11.88	"
Hydrogen	H	189.79	"
Carbonic oxide	CO	13.55	"
Carbonic acid	CO_2	8.60	"
Marsh-gas	CH_4	23.32	"

Producer gas is made from all kinds of coal, and varies in composition accordingly. Hence to study what actually goes on in the producer, we have to assume a definite composition for the coal which we are using, and measure the actual amount of carbonic acid in the gas generated. The carbonic acid in producer gas varies from 2 per cent. to 8 per cent.; the former representing very good practice, and the latter a practice that should not be tolerated. Four per cent. is the amount usually found when the producers are working rapidly and are carefully tended, and should not be much exceeded.

A low percentage of carbonic acid is usually associated with slow, cold working of the producer, and a high percentage with the reverse condition. A high percentage may also be produced by uneven firing, the gas coming up around the sides, and through "holes" in the fire, being richest in carbonic acid. The surest way to get a low percentage of carbonic acid is to run the producer slowly ; but this is not usually possible, and the best results are obtained by keeping the body of the fire well "poked" down, so that no large holes exist, and the top spread over evenly with fresh coal.

In the following tables we have assumed the composition of the coal and calculated the theoretical composition of the gas under different conditions, our object being to show what good producer practice is and to give some small impression of what is lost when the gas maker is ignorant or careless.

First we will consider anthracite coal containing 10 per cent. of ash and 5 per cent. of volatile hydrocarbons, which are practically all marsh gas (CH_4), and suppose it to be gasified by air alone. Under such conditions good gas would have about 4 per cent. of carbonic acid in it, and we remain on the safe side by assuming the gas to contain only 3.7 per cent. On this basis, column 1, in Table I, represents the pounds of gas formed ; column 2, the number of cubic feet ; column 3, the heating capacity ; column 4, the heating capacity per pound ; column 5, the heating capacity per cubic foot. The last column contains the analysis by volume. All these calculations are based on the assumption that the gas is cooled after being made ; in other words, no account whatever is taken of the sensible heat. The sum of column 3 gives the total heating capacity of the gas in terms of British thermal units. The ratio of this number to the number of heat units originally in the coal gives what we call the efficiency of conversion, or the proportion of the total heating capacity of the coal that we have in the cold gas. In this case we find it to be 64.77 per cent., but we must remember that the gas as it comes from the producer contains a large amount of sensible heat, which, under many conditions, may be utilised, but which we are disregarding.

In Tables II, III and IV we have the theoretical composition of producer

TABLE I.—ANTHRACITE GAS, WITHOUT STEAM.

100 Lbs. Coal.	1 Pounds.	2 Cu. Ft.	3 Total. B. T. U.	4 B. T. U. Per Lb.	5 B. T. U. Per Cu. Ft.	6 Anal. Per Ct. by Vol.
75 lbs. C to C O	175.0	2,371.3	756,875	4,325	319	27.79
10 lbs. C to C O_2	36.7	315.3	------	----	----	3.70
5 lbs. marsh-gas C H_4	5.0	116.6	117,500	23,500	1007	1.37
126.7 lbs. O required, associated with N	424.4	5,729.9	---- -	----	----	67.14
Total	641.1	8,533.1	874,375	Average. 1,363.9	Average. 102.5	100.00
Total energy in 100 lbs. coal			1,350,000			
Efficiency of conversion			64.77 per cent.			

TABLE II.—ANTHRACITE GAS, STEAM BLOWN PRODUCER. (Good.)

100 Lbs. Coal.	1 Pounds.	2 Cu. Ft.	3 Total. B. T. U.	4 B. T. U. Per Lb.	5 B. T. U. Per Cu. Ft.	6 Anal. Per Ct. by Vol.
80 lbs. C to C O	186.66	2,529.24	807,304	4,325	319	33.4
5 lbs. C to C O_2	18.33	157.64	------	----	----	2 0
5 lbs. volatile hydrocarbon	5.00	116.60	117,500	23,500	858	1 6
120 lbs. O required { 30 lbs. from H_2 O = H	3.75	712.50	232,500	62,000	327	9.4
120 lbs. O required { 90 lbs. from air = N	301.05	4,064.17	------	----	----	53.6
Total	514.79	7,580.15	1,157,304	Average, 2,248	Average. 152.7	100.00
Total energy in 100 lbs. coal			1,349,500			
Efficiency of conversion			86 per cent.			

TABLE III.—ANTHRACITE GAS, STEAM BLOWN PRODUCER. (Normal.)

100 Lbs. Coal.	1 Pounds.	2 Cu. Ft.	3 Total. B. T. U.	4 B. T. U. Per Lb.	5 B. T. U. Per Cu. Ft.	6 Anal. Per Ct. by Vol.
75 lbs. C to C O	175.0	2,371.3	756,875	4,325	319	30.24
10 lbs. C to C O_2	36.7	315.3	------	----	----	4.02
5 lbs. marsh-gas C H_4	5.0	116.6	117,500	23,500	1007	1.49
126.7 lbs. O required. { 32 lbs. from H_2 O = H.	4.0	758.8	248,000	62,000	327	9.68
126.7 lbs. O required. { 94.7 lbs. from air = N.	317.2	4,279.5	------	----	----	54.57
Total	537.9	7,841.5	1,122,375	Average. 2086	Average. 143.1	100.00
Total energy in 100 lbs. coal			1,350,000			
Efficiency of conversion			83.14 per cent.			

TABLE IV.—ANTHRACITE GAS, STEAM BLOWN PRODUCER. (Poor.)

100 Lbs. Coal.	1 Pounds.	2 Cu. Ft.	3 Total. B. T. U.	4 B. T. U. Per Lb.	5 B. T. U. Per Cu. Ft.	6 Anal. Per Ct. by Vol.
70 lbs. C to C O	163.3	2,212.7	706,272	4,325	319	27.3
15 lbs. C to C O_2	55.0	473.	------	----	----	5.8
5 lbs. marsh-gas, C H_4	5.0	116.6	117,500	23,500	1007	1 4
133.3 lbs. O required { 33 3 lbs. from H_2 O = H	4.16	789.2	257,920	62,000	327	9.8
133.3 lbs. O required { 100 lbs. from air = N	335.	4,522.5	------	----	----	55.7
Total	562 46	8,114.0	1,081,692	Average. 1923	Average. 133.3	100.0
Total energy in 100 lbs. coal			1,350,000			
Efficiency of conversion			80 per cent.			

TABLE V.—BITUMINOUS GAS, WITHOUT STEAM.

100 Lbs. Coal.	1 Pounds.	2 Cu. Ft.	3 Total B. T. U.	4 B. T. U. Per Lb.	5 B. T. U. Per Cu. Ft.	6 Anal. Per Ct. by Vol.
47 lbs. C to C O	109.7	1,486.4	474,460	4,325	319	23.67
8 lbs. C to C O_2	29.3	252.0	------	----	----	4.01
32 lbs. volatile hydrocarbons	32.0	746.0	640,000	20,000	858	11.88
Required 84 lbs. O, associated with N	281.2	3,796.2	------	----	----	60.44
Total	452.2	6,280.6	1,114,460	Average 2,464.5	Average 177.4	100.00
Total energy in 100 lbs. coal			1,437,500			
Efficiency of conversion			77.53 per cent.			

TABLE VI.—BITUMINOUS GAS, PRODUCER STEAM BLOWN (Good).

	1	2	3	4	5	6
100 LBS. COAL.	Pounds.	Cu. Ft.	Total B. T. U.	B. T. U. Per Lb.	B. T. U. Per Cu. Ft.	Anal. Per Ct. by Vol.
50 lbs. C to CO	116.66	1,580.7	504,554	4,325	319	27.8
5 lbs. C to CO_2	18.33	157.6	------	----	----	2.7
32 lbs. volatile hydrocarbons	32.00	746.2	640,000	20,000	858	13.2
Required 80 lbs. O { 20 lbs. from H_2O=H	2.50	475.0	155,000	62,000	327	8.3
Required 80 lbs. O { 60 lbs. from Air=N	201.00	2,709.4	------	----	----	48.0
Total	370.49	5,668.9	1,299,554	Average 3,507	Average 229.2	99.8
Total energy in 100 lbs. of coal			1,437,500			
Efficiency of conversion			90.0 per cent.			

TABLE VII.—BITUMINOUS GAS, PRODUCER STEAM BLOWN (Normal).

	1	2	3	4	5	6
100 LBS. COAL.	Pounds.	Cu. Ft.	Total B. T. U.	B. T. U. Per Lb.	B. T. U. Per Cu. Ft.	Anal. Per Ct. by Vol.
45 lbs. C to CO	105.0	1,422.7	454,125	4,325	319	24.0
10 lbs. C to CO_2	36 7	315.3	------	----	----	5.3
32 lbs. volatile hydrocarbons	32.0	746.2	640,000	20,000	858	12.6
Required 86.7 lbs. O { 21.7 lbs. from H_2O=H	2.7	512.2	167,400	62,000	327	8.6
Required 86.7 lbs. O { 65. lbs. from Air=N	217 6	2,937.6	------	----	----	49.5
Total	394.0	5,934.0	1,261,525	Average 3,201.8	Average 212.6	100.0
Total energy in 100 lbs. coal			1,437,500			
Efficiency of conversion			87.8 per cent.			

TABLE VIII.—BITUMINOUS GAS, PRODUCER STEAM BLOWN (Poor).

	1	2	3	4	5	6
100 LBS. COAL.	Pounds.	Cu. Ft.	Total. B. T. U.	B. T. U. Per Lb.	B. T. U. Per Cu. Ft.	Anal. Per Ct. by Vol.
40 lbs. C to CO	93.	1,260.2	402,225	4,325	319	20 4
15 lbs. C to CO_2	55.	473.0	------	----	----	7.7
32 lbs. volatile hydrocarbon	32.	746.2	640,000	20,000	858	12.0
93 lbs. O required { 23.2 lbs. from H_2O=H	2.9	550.1	179,800	62,000	327	8.9
93 lbs. O required { 69.8 lbs. from Air=N	233.8	3,156.1	------	----	----	51.0
Total	416.7	6,185.6	1,222,025	Average 293.3	Average 197.5	100.0
Total energy in 100 lbs. of coal			1,437,500			
Efficiency of conversion			85.0 per cent.			

TABLE IX.

PER CENT.	WITHOUT STEAM.		STEAM BLOWN PRODUCER.					
			ANTHRACITE GAS.			BITUMINOUS GAS.		
	Anthracite Gas.	Bituminous Gas.	Good.	Normal.	Poor.	Good.	Normal.	Poor.
Carbonic acid, CO	27.79	23.67	33.4	30.24	27.3	27.8	24.0	20.4
Volatile hydrocarbon	1.37	11.88	1.6	1.49	1.4	13.2	12 6	12.0
Hydrogen, H	----	----	9 4	9.68	9.8	8.3	8.6	8.9
Carbonic acid, CO_2	3.70	4.01	2 0	4.02	5.8	2.7	5.3	7.7
Nitrogen, N	67.14	60.44	53.6	54.57	55.7	48.0	49.5	51.0
Combustible	29.16	35.55	44.4	41.41	38.5	49.3	45.2	41.3
Of original energy in gas	64.77	77.53	86.0	83.14	80.0	90.00	87.8	85.0
B. T. U. per lb. gas	1364.00	2464.00	2248.00	2086.00	1923.00	3507.00	3202 00	2933.00
B. T. U. per cu. ft. gas	102.5	177.4	152.7	143.00	133.30	229.00	212.6	197.5

gas from the same coal, on the supposition that one-fourth of the oxygen needed is derived from the steam, which both theory and practice indicate as about the proper amount.

These tables give the composition of the gas with increasing amounts of carbonic acid; and it will be noted that with increase of carbonic acid, not only does the efficiency of conversion decrease, but also do the number of heat units per pound and per cubic foot of gas. As a matter of fact, the amount of carbonic acid in gas is a very good index of its quality.

In Table V we have a composition of bituminous coal gas made without steam, such as is made in the Siemens producer, the coal being assumed to contain 55 per cent. carbon and 32 per

cent. volatile hydrocarbon; and we find the efficiency of conversion to be 77.53 per cent. It must be remembered, however, that this gas is very hot when it comes from the producer, and, if used without cooling, would have a much higher efficiency. The increase of efficiency over anthracite gas of like manufacture is due to the high percentage of volatile hydrocarbons, which, while they may not be all marsh-gas, will have a heating capacity of at least 20,000 B. T. U. per pound. On the other hand, however, if the gas is cooled, a large proportion of the volatile hydrocarbons will be deposited as tar. In fact, if we analyse the cool, fixed gas, we shall not find it very different from similar anthracite gas; but if we use it hot from the producer before the hydrocarbons have been deposited, it is much richer.

Tables VI, VII and VIII give the compositions of steam-blown bituminous gas with increasing proportions of carbonic acid. It will be noted here also, that as the carbonic acid percentage increases, the efficiency of conversion and the richness of the gas decrease. For the sake of accurate comparison, the volumetric analysis and the results of the foregoing calculations for different gases are arranged together in Table IX.

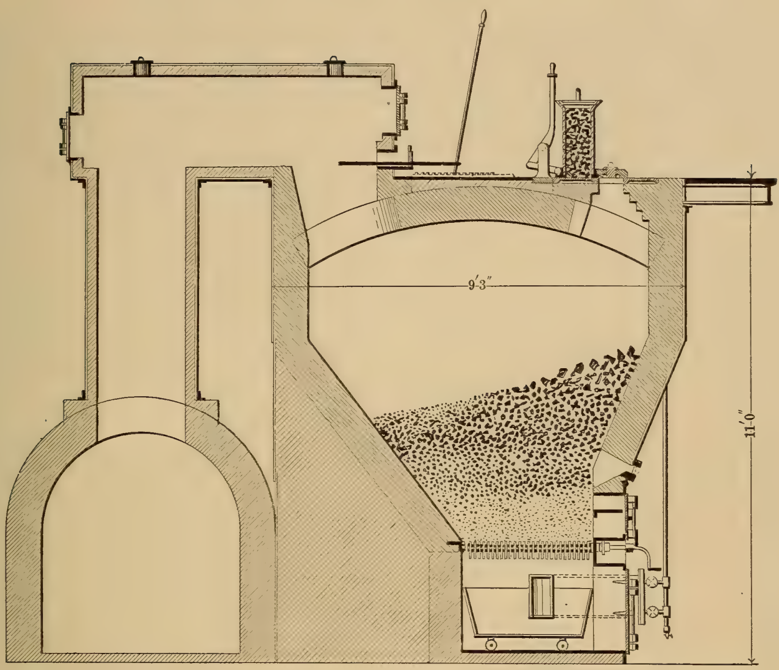
It must be remembered, however, that the first two gases came from the producer hot, and should, if possible, be used at once, in which case they will be more efficient than the figures indicate; but if allowed to cool, the anthracite gas will lose nothing but its sensible heat, while the bituminous gas will lose some of its hydrocarbons by condensation. As many of the volatile hydrocarbons in bituminous coal are readily condensable, no gas from such coal, if allowed to cool at all, is as rich as the figures in the table indicate.

The facts that bituminous coal can be converted into gas with less loss than anthracite, and that the resulting gas is richer, are strong points in favour of its use in the producer. In many places, however, especially where the presence of tar and soot cannot be tolerated, anthracite gas does very well, but the 50 per cent. more heat units per cubic foot in the bituminous gas count enormously in the production of high temperatures. Indeed, for the production of temperatures comparable with those of the Siemens steel melting furnace a rich gas is essential for economical working, and a steel melter can tell at once by the action of the furnace whether the producers are being properly tended or not.

Table IX may be very advantageously studied by the users of producer gas, and the calculations carried out for larger percentages of carbonic acid. With increasing percentages of carbonic acid in the gas, we find not only a decrease in the efficiency of the gas making, but an increase in the amount of nitrogen, and a marked decrease in the amount of combustible material in the gas. It is hard to overestimate the effect of this impoverishment, especially in the production of high temperatures. The loss in conversion is only a small part; the great loss comes in the increased amount of gas needed to do the same work, and if the required temperatures are very high the poor gas soon becomes entirely inadequate, no matter in what quantity it may be used.

A brief reference to some of the various kinds of producers now in use, may not be uninteresting here. The one first demanding our attention is the Siemens producer, which is the oldest form, having made its advent with the open hearth furnace. In it no steam is used, and natural draught, induced by the syphon-like action of large cooling tubes, is the means by which gas is conveyed to the furnace. The gas from the Siemens producer is essentially a hot gas; hence, the waste from loss of heat in the cooling tubes must make its efficiency low, although not as low as is indicated in our table, which supposes the gas to be cooled to 62° F.

This producer seems to us to-day very wasteful and crude, but we must remember that it made a success of the Siemens furnace, and while we are at



GAS PRODUCER BUILT BY MESSRS. SWINDELL & BROS., PITTSBURGH, PA., U. S. A.

liberty to show the advance in the art by comparing more recent producers, our criticism should always be made with a proper appreciation of what it has done for metallurgy. If we close up the ash-pit of the Siemens producer and put on a steam blast, we improve it very much, and get the producer which, in various shapes and under as many names, is in most common use.

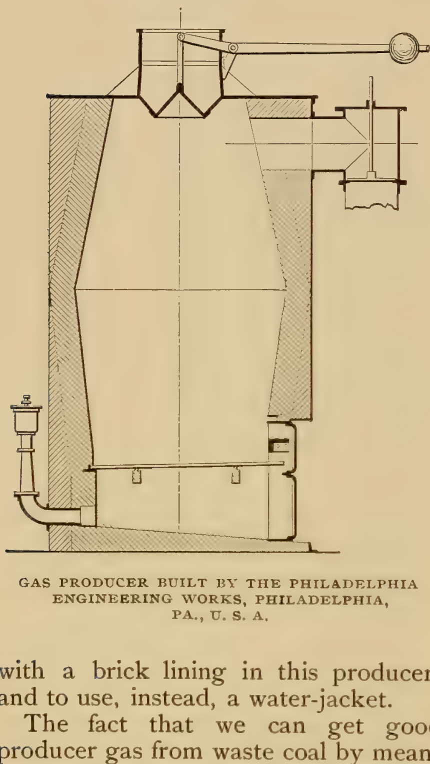
All these later producers have what may be called a cinder grate ; in other words, the bars are always kept covered with a deep bed of cinders, which are always small and soft, due to the fact that producers blown with steam are never hot enough to fuse the cinders into large, hard masses.

Among this class of producers may be mentioned the Swindell, which is a modified Siemens with a closed ash-pit, and shaking-grate bars, illustrated on this page. These producers are giving good results, and are being introduced in large numbers. As an example of a continuous producer with a water seal, may be mentioned the Smythe, shown on page 53. This producer, having a large grate area, would seem well adapted for burning waste coal, and, indeed, this is what its makers specially claim for it.

Attention, too, may be called to the Taylor producer, which differs from all the others in that it has no grate, properly speaking, but a circular revolving plate on which rests the entire burden. A bed of cinders of considerable depth rests on this plate, through the centre of which is a pipe for the admission of air and steam. This means of admitting the air avoids, to the greatest possible extent, one serious trouble in producer practice, namely, "blowing through" along the walls.

A glance at the cut on page 54 will show the apparatus and method of cleaning the fire. When the plate is revolved by means of the crank, the cinders are ground up and fall over the edge, the frequency of grinding and the number of revolutions depending on the rate at which the producer is being forced. The fact that here the

grate is practically a large bed of cinders, would indicate the possibility of using in this producer the smaller grades of coal. In fact, a large number of these producers are being run with satisfactory results on anthracite, buckwheat and bituminous slack. For many purposes it has been found advisable to dispense



GAS PRODUCER BUILT BY THE PHILADELPHIA ENGINEERING WORKS, PHILADELPHIA, PA., U. S. A.

with a brick lining in this producer, and to use, instead, a water-jacket.

The fact that we can get good producer gas from waste coal by means of any one of the two or three producers, suggests the possibility of this method of utilising such coal for the firing of boilers. Quite a little work was done in this line a few years ago by some engineers, and the results were very satisfactory; but the advent of the successful mechanical stoker seemed so completely to fill the gap, that, for the most part, experiments in this line were discontinued.

There is, however, one boiler plant fired in this manner now running in the United States with such excellent results that it may be interesting to present it in detail. We are able to do this, as the plant was an experiment, and subjected to a scientific investigation. The plant in question, the results of which have been kindly put at my disposal, is at the works of R. D. Wood & Co., at Camden, N. J., Taylor producers being used. The boilers were erected for direct firing, and in taking the gas from the producer, the conduits and other details were not arranged as they would have been in a plant specially designed for the purpose. In fact, the gas conduits run through sandy ground with clay immediately underneath, and, being of a temporary character, there was more or less leakage of water into them, so much so that while the test in question was going on, a stream of boiling water was drawn from the conduit to keep it clear. The result of this was that not only the temperature of the gas fell from over 600° F. at the producer to 300° F. at the boiler, but the gas carried with it a large quantity of vapour which further reduced its efficiency.

In this experimental plant two No. 7 producers are used,—one of the ordinary brick-lined type, and the other, water-jacketed, the jacket serving as a feed-water heater. The feed-water enters the boilers at a temperature of 298° F. The coal used was anthracite buckwheat, containing about 25 per cent. of ash and refuse, and the resulting gas contained about 4 per cent. of carbonic acid. The temperature of the air entering the boilers through ducts in the setting was 200°, and that of the chimney gases 415° F. The steam used to blow the producers was 6⅔ per cent. of the water evaporated; the chimney gases contained 1 per cent. of CO, 13.7 per cent. of CO_2, and 4.7 per cent. of O.

The test made under the above conditions gave the following results:

Water evaporated per pound of fuel	7 lbs.
" " " combustible	8.7 "
Water evaporated per pound of combustible from and at 212° F.	10.5 "
Horse-power of boiler with gas firing	91
" " " direct firing	65

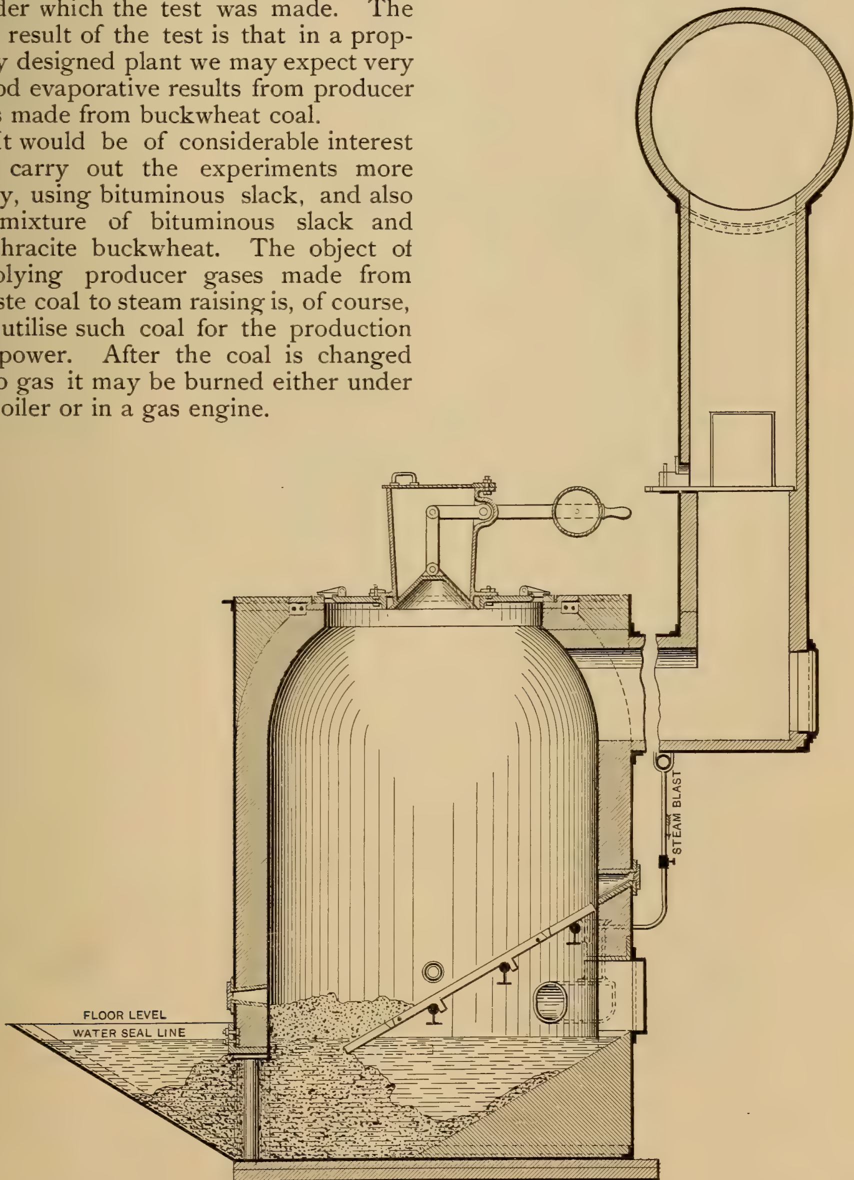
The most interesting fact to be noted in these results is an increase of nearly 50 per cent. in the capacity of the boiler. This is, undoubtedly, due to a number

of conditions which accompany gas firing, among which may be cited the following :—The tubes do not become clogged with dust ; the door is never open to admit cold air ; and the fire is never cooled down with fresh coal. The generation of steam is absolutely uniform, and the evaporative efficiency is good considering the conditions under which the test was made. The net result of the test is that in a properly designed plant we may expect very good evaporative results from producer gas made from buckwheat coal.

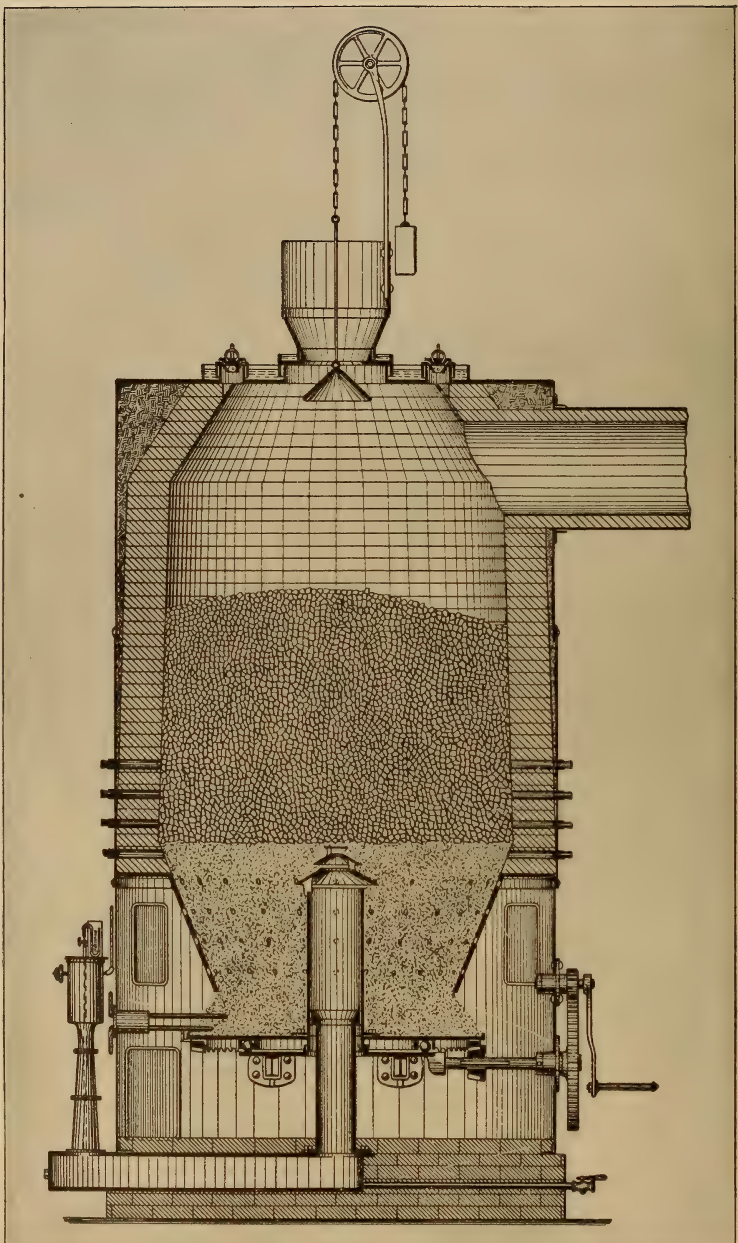
It would be of considerable interest to carry out the experiments more fully, using bituminous slack, and also a mixture of bituminous slack and anthracite buckwheat. The object of applying producer gases made from waste coal to steam raising is, of course, to utilise such coal for the production of power. After the coal is changed into gas it may be burned either under a boiler or in a gas engine.

Having seen what has been accomplished in boiler firing, it is interesting to note what has been done by the use of such gas in a gas engine direct.

The writer has available the record of two tests, one of a 100 horse-power Otto gas engine, running on producer gas at the works of the Otto Gas



PRODUCER BUILT BY THE S. R. SMYTHE CO., PITTSBURGH, PA., U. S. A.



THE TAYLOR REVOLVING BOTTOM GAS PRODUCER, BUILT BY MESSRS. R. D. WOOD & CO., PHILADELPHIA, PA., U. S. A.

Engine Company, of Philadelphia; and the other, of two 100 horse-power Otto gas engines at the plant of the Danbury & Bethel Gas and Electric Light Company, at Danbury, Conn., U. S. A. A detailed account of the first test, made by Prof. H. W. Spangler, of the University of Pennsylvania, is given in the journal of the Franklin Institute for May, 1893. The second account was presented by Mr. A. W. Burchard, M. E., before the American Society of Mechanical Engineers in May, 1895.

We shall describe somewhat in detail the method employed at the Otto Gas Engine Works, following Prof. Spangler's paper. The engine used for the tests, and which furnishes the power for the shops, does not differ materially from the ordinary Otto gas engine. The gas used is made from anthracite buckwheat coal by a Taylor producer, and passes through two scrubbers to a holder. The first scrubber is divided horizontally in the centre by a water-seal, and the gas entering the bottom of the upper section, rises to the top and is conveyed to the bottom of the second scrubber, from the top of which it passes to the gas-holder. The producer is blown by a Root blower, the blast from which enters the bottom of the lower section of the first scrubber, and, rising through the heated water, issues from the top of this section quite hot and thoroughly charged with moisture. It is then led directly to the producer.

The water for the scrubbers comes from a tank above, and, in the first scrubber, is highly heated by the gas as it comes from the producer; but it gives up the larger portion of its heat to the air of the blast, and leaves the scrubber at the bottom, much reduced in temperature. It is found that the air passing through the heated water of the scrubber takes up enough water to obviate the necessity of a steam boiler in connection with the producer.

The fuel used was anthracite buckwheat, and the average composition of the gas, from seven determinations, extending over three days, was as follows:

		Per Ct. by Vol.	Per Ct. by Wt.
Carbonic oxide	CO	25.38	26.08
Hydrogen	H	4.51	0.33
Marsh-gas	CH_4	1.79	1.05
Oxygen	O	0.26	0.23
Carbonic acid	CO_2	4.02	6.50
Nitrogen	N	64.04	65.81

The composition of the exhaust gases was as follows:

		Per Ct. by Vol.	Per Ct. by Wt.
Carbonic acid	CO_2	15.60	22.44
Oxygen	O	2.24	2.34
Carbonic oxide	CO	0.23	0.22
Nitrogen	N	81.93	75.00

Without going into any long and intricate calculations the results may be stated as follows:

Coal used per indicated horse-power per hour	0.9511 lbs.
Coal used per brake " "	1.315 "
Combustible per indicated " "	0.8302 "
Combustible per brake " "	1.148 "

The difference between the indicated horse-power and that measured by the brake seems very large,—in fact, the actual horse-power is only 72 per cent. of the indicated. This may be accounted for, to a large extent, by the fact that the engine was entirely new.

In the test of the Danbury engines, the brake horse-power was found to be 87 per cent. of the indicated; hence, it is reasonable to suppose that when the engine considered above got into equally good working shape, its mechanical efficiency would also be 87 per cent., both being the same kind of engine. Calculating its effective horse-power on this basis, we find that it should require only 1.09 lbs. of coal, or 0.95 lbs. of combustible per brake horse-power per hour. But little work has been done in this line, and the fact that such favourable results have already been obtained argues very well indeed for the future.

So far, we have dealt with the subject purely from an engineering standpoint, but, however favourable the results may appear when looked at in this way, we must always remember that there is another and more important side to the question. What we are seeking in this work is to get power at as small a cost as possible, and we must remember that cost of plant always enters into the question as a large factor.

For small powers, undoubtedly the

cost of producer, scrubbers, gas-holder, blower and gas engine seem very large when compared with that of a steam boiler and engine ; and it is a question of calculation as to how much more we can afford to pay for the gas plant than for the steam boiler. For larger powers, however, the cost of the gas plant compares more favourably with that of the boiler, as the most expensive part, the holder, need not be any larger for a thousand horse-power than for a hundred. We may safely say that there is a point somewhere between one hundred and one thousand horse-power at which the cost of the gas plant does not exceed that of the boiler plant ; and also, that beyond this point, a gas engine, working under the conditions described, is more economical than a steam engine. The location of this point is determined solely by commercial considerations ; and the question as to whether a small gas power can be used economically is quite susceptible of calculation when we know the cost, both of the steam and of the gas plant, and the saving in coal of the latter over the former.

To day all steam engines are sold on a guaranteed steam consumption, and the boilers on an evaporation per pound of coal or combustible, so that it is easy to estimate the cost of the power generated by steam. Can we as easily calculate the cost of power generated by the gas plant? We can at least safely say that what has already been done can be done again, and the writer believes that it will be done better in the near future.

It is too soon to make any kind of a prediction, but the indications are that the gas engine has before it a much wider field than has been hitherto supposed, and we need not be greatly surprised if in a short time we find engineers considering, not the question of the kind of steam engine they need, but whether they want a steam engine at all. When as much attention and study is given to gas engines as is devoted to steam engines, and when people are willing to place in them the confidence that they deserve, we must not be surprised to see the gas producer as a formidable competitor of the steam boiler.

ELECTRIC POWER FROM THE COAL REGIONS.

By Dr. Louis Bell.

THE rise of electric power transmission has opened to us the gateway to many economic and social advances as yet only partially understood and half appreciated. The work of evolving methods and putting them into practice has gone on with immense rapidity in the last two or three years, yet with so little blare of trumpets that very few, outside of those most immediately interested, realise how effective are the methods and how certain the results.

The public knows that Niagara has, after several years of hard work, been "harnessed," to use the pet reportorial word, and, as a beginning, that colossal plant has gone into service making aluminum. The public knows, too, that the reporter, with facile pen and deft imagination, has published weird accounts of how Niagara is to run all the railroads in the country, supply light and power to every city and irradiate the country generally. In fact, sun, moon and stars might well be forgot on and after the full starting of the Niagara plant if b'r'er reporter has the facts correctly.

But the public does not know how much of the credit for the splendid work at Niagara lies not with the electrician but with the determined, hard-working, persistent men who, with the courage of their convictions, pushed ahead, year after year, carrying the financial burdens of the gigantic enterprise in face of seven legions of croakers. Long before a wheel turned at Niagara the electric railroads had proved, beyond dispute, that electric power could be distributed over wide areas with entire success and without inordinate expense, and when, a few months since, Niagara went steadily to work there were already running half a hundred plants for the electrical transmission of power, that had tested and proved every principle of the art by the final touchstone of experience, so that it was absolutely certain that nothing save bungling could make Niagara a failure.

There is many a question asked today that shows only too clearly how little impression all this unheralded work makes on the public mind, and how feeble is the realisation of what has already been accomplished and its bearing on what is about to be done. It is the purpose of this brief article to answer some of the pertinent and searching questions that intelligent men are still asking, not after the manner of the scribes, who paint in glowing colors the marvels which they think ought to be accomplished by the "mysterious force" of which they love to speak, nor yet after the manner ot those who prove it all by well marshalled equations recruited from half a dozen alphabets. On the contrary, these questions are to be answered by a direct reference to the facts which experience has already shown regarding them. We will not venture to go beyond experience save on roads constructed of it.

The first and most natural question is : Can electrical power be distributed

cheaply over large areas? In the first place, we may note that nearly every large city is provided with a network of electric railways that stretch far out into the suburbs. The horse has practically been driven out of the business. These railways adopted the electric system not for humane or æsthetic reasons, but because it was cheap and effective. The rapid transit system of Boston, Mass., U. S. A., for example, has been steadily growing for half a dozen years. It serves today a population of nearly a million people over a radius of ten miles or so, and it has thus grown because it was cheap and did its work well. Passing from this special class of work, we find the Edison central stations for the supply of electric light in New York city now operating over its entire lighting area, electric motors to the aggregate capacity of something like eight thousand horse-power, — an amount that has been steadily increasing for years. These motors are employed in almost every imaginable kind of service and place.

These stations are by no means eleemosynary institutions, nor are the hundreds of people who use motors, engaged in unprofitable recreation. The stations furnish electric power because it is profitable, and the users employ it because it is cheap and by far the best power to be had. In every large city it will be found, on investigation, that electric power is being used with growing frequency, in large amounts and over areas of many square miles. Those who sell electric power, find that it pays to do so, and those who buy it find it to their interest.

But, granting this, is electric power reliable? Well, people are not in the habit of using unreliable power when there is better to be had, and the growth of electric motor service shows that experience has answered the question in the affirmative. You frequently hear of people taking out steam engines and putting in electric motors, but you seldom find them throwing those motors out because they are unreliable, or for any other reason. In similar fashion the street railway men, while they are using motors in every sort of fashion, find them, on the whole, reliable. Now and then a motor may be indisposed and laid up for a few days in the repair shop, but, in general, motors do not go lame, or cast a shoe, or have the blindstaggers, or the epizootic or anything of the sort. They are not perfect,—few machines of human contrivance are,—but they are perfect enough to have assumed the responsibility of the rapid transit work in nearly every American city, and to have acquitted themselves well. If this is not enough evidence that the electric motor is trustworthy, we may cite some of the newspapers that run their presses by electric power and generally manage to come out on time; and a couple of big cotton mills, one at Columbia, S. C., U. S. A., and the other at Pelzer, in the same State, that have no power but electric to drive their looms and spindles.

Cotton mills are peculiarly fussy about the continuity of their power, for stopping even a few minutes means serious loss. And when one has been running a year and a half, as at Columbia, driven by electric power alone, and its managers are outspoken in their satisfaction, we may conclude that the service has been trustworthy. The fact is that in spite of no small popular distrust at the start, electric power has proved reliable and has gradually made its good character known.

But granted that the distribution of electrical energy from central stations has proved its advantages, how about transmitting it long distances, so as to supply large districts, not from some central point, but from a distant source of power? Of the mere fact of transmission and distribution for motor service we have plenty of evidence. For a couple of years there has been a power plant supplying electrical energy to the city of Genoa, in Italy, from a point eighteen miles distant. It has done steady and excellent service, supplying several scores of motors employed in all sorts of industries, and

this although the methods are, from our present standpoint, somewhat crude. For an equal length of time power has been regularly supplied for the driving of the electric light machinery at Hartford, Conn., U. S. A., from a water-power eleven miles away; for working the machine shops of the Oerlikon Company, at Zurich, Switzerland; for running the ore mills in Telluride, Col., U. S. A.; and for operating an artificial ice factory and doing miscellaneous lighting and power at Redlands, Cal., U. S. A., at distances only slightly less than the above. In all these cases the power has proved to be steady and economical.

For periods of time ranging from two years down to a few months, not less than fifty power transmission plants have been working regularly in different parts of the world, ranging in magnitude from Niagara down to fifty horse-power, and in distance from the Folsom-Sacramento transmission, in the United States, having an extreme length of about 25 miles, down to a mile or two. All these plants have been singularly free from trouble, and have done their work well.

Admitting that distances up to twenty or twenty-five miles can be successfully overcome, is there a reasonable probability that the transmission of power can be extended over distances much greater? Yes, if necessary. We have no plants over twenty-five miles, but the methods and apparatus for longer transmission have already been thoroughly tested, and up to at least fifty miles we are sure of our ground,—perhaps up to a hundred miles. The transmitting and receiving machinery would be quite identical whether the line between them were twenty or fifty miles long, so that, as regards apparatus, the ground is well trodden.

For very long transmissions, high electrical pressure is necessary to keep down the cost of the line, since the amount of copper required to meet given conditions decreases with the square of the voltage. And we have already experience with the voltage just as with the apparatus,—at least with voltages ample for a fifty-mile transmission. For example, without counting the famous Lauffen-Frankfort experimental plant, with a line 108 miles long, and operated part of the time at a pressure of nearly 30,000 volts, there are now in commercial service four plants, running steadily and successfully at pressures of 10,000 volts and more. Chief among them is the Oerlikon installation in Switzerland, working at over 14,000 volts; then come Folsom-Sacramento, in the United States, and Guadalajara, in Mexico, at 11,000 each; and finally the San Antonio canõn plant, in the United States, at 10,000. The first and last mentioned have been in operation nearly three years without having encountered any appreciable difficulty from the very high pressure. The other two have been operated some months without a trace of trouble. From these experiences there is the best of reason to believe that voltages up to fourteen or fifteen thousand are entirely justified by present practice.

Concerning distances of 100 miles or more, and pressures exceeding 15,000 volts, we have only the results at Lauffen by way of data. While these make no pretense of representing commercial practice, they still are good evidence that, as an engineering feat, a transmission of a hundred miles at 25,000 or 30,000 volts is quite practicable. While the feasibility of covering far greater distances at much greater voltage is more or less a matter of speculation, those who know most about the difficulties to be met fear them the least.

But, after all, does this sort of thing pay? This is the real crucial question, and the future of power transmission depends upon the answer. With most of the transmissions mentioned, in fact nearly or quite all of those which have been running long enough to draw any conclusions, experience has said "Yes" in unmistakable tones. So far as has yet appeared, any lack of commercial success has been due to other causes than the cost of electrical transmission.

Up to the present time substantially

all the transmissions of any magnitude have been from water powers, and it is singular to note how their success has stimulated their production. Water powers have been discovered in unheard-of nooks, and even where they were hardly suspected. But there is an end to such discoveries, and sooner or later, beginning in the very near future, something must be done with the next largest amount of unused energy remaining. This is to be found in the huge store of fuel that is our legacy from the carboniferous age. How great it is we can only guess, for we have perhaps hardly begun to take account of it. Yet this is no reason why we should play the spendthrift with that which we now have. Huge piles of waste coal are landmarks in every mining region, and below ground are enormous masses, untouched as yet because of poor quality.

The transportation of coal is really a special case of the transmission of energy, and we may with perfect fairness compare it with electrical transmission. If it be cheaper and easier to ship coal from the mine to the point of consumption than it is to burn the coal at the mine and transmit the resulting energy, then the latter course must show cause for its existence. Coals, we know, have varying values as fuel, while the cost of mining and transportation is fairly uniform. Hence, any examination of the question just raised must take this difference into account.

The first thing to be done in studying the problem of the transmission of power from cheap coal at the mines is to get at some common basis of comparison between carrying the energy in bulk and sending it over a wire. Fortunately, experience has already shown that in ordinary distribution of power through a city, there is a gain in generating it in large quantities and distributing it electrically in the ordinary small industrial units. Hence, we can confine ourselves to comparisons on a large scale.

Knowing that a large central station can distribute power economically, can it the more cheaply generate it by coal burned on the spot, or by power transmitted from a region of cheaper coal? What is true in this case will be also true of large units of power devoted to other purposes. We can get our common unit in the following way :—

A good engine, of compound condensing pattern, is capable of producing 1⅓ horse-power-hours, *i. e.*, 1 kilowatt-hour by the consumption of about 2 pounds of good coal. Whether the coal or the current be transmitted, the engine will be used, so that, for a rough approximation to the economics of the matter, we need only compare the cost of the electric transmission per 1000 kilowatt-hours with the expense of freighting and handling one ton of coal. The cost of the transmission means here simply the interest, care and depreciation on the electrical part of the total plant. This we can very readily approximate.

The cost of line and apparatus for a fifty-mile 15,000 volt transmission in large amount may be reckoned at something like $100, or about £20, per kilowatt transmitted. Taking interest, labour and maintenance at twenty per cent. and assuming 3000 working hours per year the charge for transmission becomes over 0.6 cent or about 0.3d. per kilowatt-hour. This evidently corresponds to a prohibitive and absurd freight rate for the distance. Even if by increasing the magnitude of the transmission and raising the voltage we were able to reduce this by one-half, we should still have a cost of transmission far greater than the cost of transporting the necessary coal. In the present condition of affairs it is then quite evident that with good coal, transportation can more than hold its own against electric transmission. Even with coal only half as good as that which we have assumed, the same condition holds good.

On the other hand, the transportation under certain circumstances may be so expensive as to throw the balance quite the other way. In some mining regions, where fuel has to be carried for miles over the mountains on mule back, such a transmission as we have

been considering might very well pay handsomely. Nevertheless, we are entirely safe in saying that where there are fairly good facilities for transportation, and good coal is under consideration, electric transmission is at a very manifest disadvantage.

But there is another side to the question. In all mining there is produced a varying, but considerable, proportion of coal which is unfit for transportation and sale, and now simply encumbers the earth. It is worse than useless, because it has to be disposed of in some way. It is this coal to which we must look for energy which can profitably be transmitted. The competition is not here between freightage and electrical transmission, but between power produced from coal costing, perhaps, three or four dollars (12 to 16 sh.) per ton, and coal costing a few cents per ton. The latter may be poor, indeed, but, still, it is cheap fuel. If it can be utilised to generate power twenty-four hours a day, the charge for transmission, plus the cost of fuel, may sink so low as to fall below the fuel cost at some outside point under consideration.

For instance, the charge of 0.6 cent or 0.3d. per kilowatt-hour previously computed, may readily sink to 0.4 cent or 0.2d. at a more moderate distance, and to less than half that for twenty-four-hour service, even including culm for fuel. At this cost it would come into active competition with power produced on the spot, even with fairly cheap coal and very good engines. A plant deliberately installed to burn culm, on a very large scale, and running 24 hours a day with a fair load, can probably be made to put electrical energy on the line at or very near 0.3 cent or about 0.15d. per kilowatt-hour. Taking into account the cost of a moderately long transmission, as noted above, it seems probable that, including the losses of efficiency in transmission, one mechanical horse-power-hour could be delivered anywhere within, say a radius of twenty miles, at an actual cost of one-half to two-thirds of a cent, or say about 0.25d. And the horse-power-hour could certainly be sold for decidedly less than it now costs the average large consumer of power. The economy of such a plant is based both on cheap fuel and a large and relatively continuous service. The former item is acquired in virtue of the electrical transmission for which it more than pays.

Another and equally interesting field for transmission on a large scale lies in the existence of much coal of poor intrinsic quality which stands shipment poorly, being too soft and friable. Such coal can, and does, often exist in regions where good coal is very dear. In this case the ability to substitute cheap for costly fuel is quite sufficient to overcome the cost of even a long electric transmission. It may pay to carry the power even fifty miles or so, and one such case, carefully investigated by the author in some detail, showed that it actually would pay even with so long a distance to be overcome.

While coal is plentiful and water powers still remain unutilised, of course the temptation to work in the direction of colossal transmissions from cheap coal is partially removed. Yet it should not be forgotten that coal ought never to be cheap enough to throw away, and water powers are often of deceptive value. It often happens that the expense of developing them makes the investor sad, and wherever cheap coal is available it deserves to be thoroughly investigated with reference to the possibility of electrical transmission.

The present state of the case is that on a large scale the transmission of power from the culm pile, or the now unworked coal mine, over even considerable distances stands a good chance of commercial success. The larger the plant and the steadier the service, the greater the distance over which power can be sent to compete with that generated on the spot. In a desultory way and on a small scale the chances of success are not particularly good, unless under very unusual circumstances.

Aside from all the commercial aspects of the case there is something to be said for the æsthetics of it. Large cities and small ones, too, suffer from the

abominable soot and smoke that pour out from scores or hundreds of ill-managed steam plants. On a muggy day the very fumes of the pit settle down over the habitations of men and burden the air. The time ought to come when London fog and the passable imitations of it to be found elsewhere shall have become matters of ancient history, with plague and famine. The place to burn fuel is where it will least interfere with human avocations and pleasures,—not about the dwelling places and under the noses of all mankind.

Some day we may reach a state of civilisation that will realise all this to the extent of reformation. This briet paper will have served its purpose if it has pointed out that even now the means are at hand, and the end may be served even by selfish interest. As the art grows so will the commercial opportunity and the hope of a more rational conduct of industry.

MODERN COAL HANDLING MACHINERY.

By A. J. Webster.

THERE are few factors more necessary to the successful management of manufacturing enterprises than cheap fuel. This appeared to be fully recognized when natural gas was discovered in quantity in the United States, and the massing of manufacturing plants within the gas belts immediately followed. With the partial failure of the gas, however, the problem of utilising the cheaper fuels became a living question to the progressive manufacturer and engineer. Power plants of every description increased rapidly in size, and the heavy daily consumption of fuel brought forward prominently also the problem of its cheap storage and handling. The time was, when the steam users thought it compulsory to use nothing but the best lump fuel, but under the changed conditions of to-day, the culm piles of both anthracite and bituminous regions furnish not a little of the fuel for large steam users.

The first step toward the practical utilisation of the cheaper fuels was the introduction of the mechanical stoker. This device made it possible to use them with marked economy and better general results. Coincident with its introduction came the elimination of the slow and expensive barrow and shovel as factors in stoking, and the substitution of fuel handling machinery,—not the modern outfit of to-day, but a crude imitation of appliances used for handling cereals and other light substances, inadequate in all or many respects.

Gradually, did the magnitude of the field opened up to manufacturers in this particular line of machinery impress itself upon them, and the brains of inventors and the skill of engineers were called into requisition to evolve systems for handling fuel, strong and efficient in construction, and inexpensive in first cost and maintenance, compared with the beneficial results secured. With improved devices, better materials and skilled engineering, results are now obtained that a few years ago would have been deemed impossible. Distance counts for little as a factor in the installation of these plants ; railway tracks and roadways are tunnelled or spanned by steel trusses and in many instances fuel is delivered to power buildings located fully

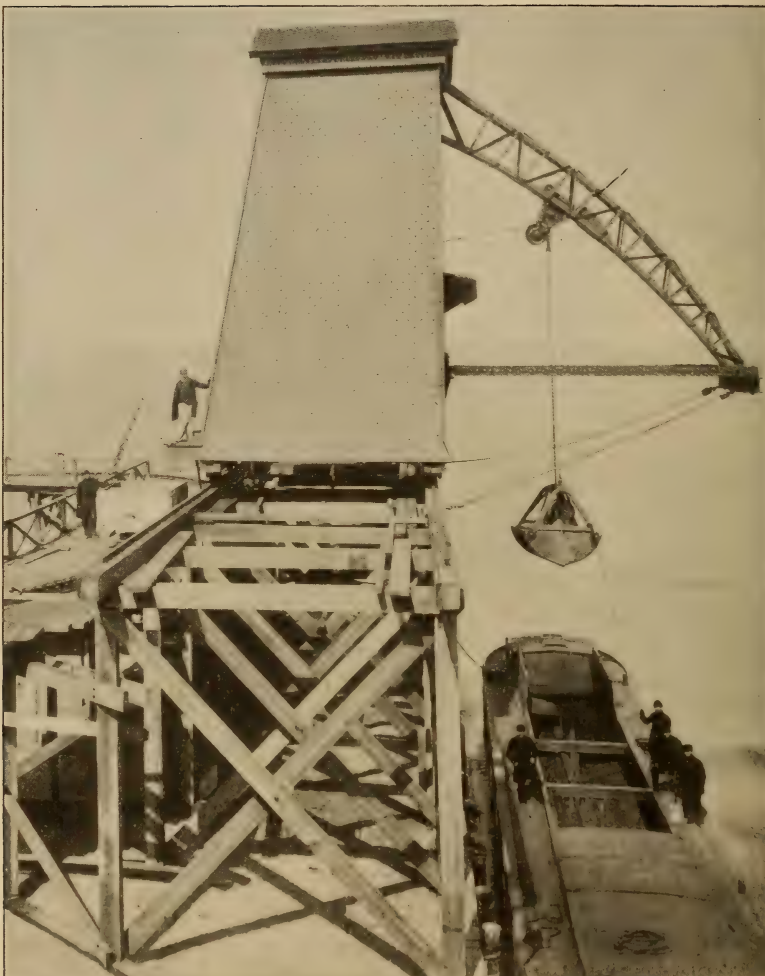
A CONVEYOR OUTFIT, BUILT BY THE JEFFREY MFG. CO., COLUMBUS, OHIO, U. S. A.

a thousand feet from the storage grounds.

Modern fueling plants are no longer a luxury. With the imperative demand for the closest economy and the arbitrary requirement of a reserve quantity of fuel of greater or less magnitude to draw upon in case of strikes, storms or other causes that lead to short fuel supplies, the best machinery for handling coal has become a necessity, and to the engineer no less than to the power user the study of its design and construction is full of interest and profit.

It is a common idea that because coal is heavy and dusty, coal machinery is rough and coarse; but this is a wholly mistaken belief. No Waltham watch or compound locomotive is more carefully designed, the details more thoroughly studied, or the materials more carefully selected and put into shape, than are the working parts of the coal handling appliances turned out by the high-class makers of to-day. It may seem, at first sight, to be a useless refinement to work to templets, to turn shafts to vary less than a minute fraction of an inch, to make taper fits, and to indulge in various other refinements of modern mechanism on machinery that is to be roughly handled, covered with grease and dust, and exposed often to all the inclemencies of the weather; and yet, all this has been found to be right in the line of positive economy. Durability and freedom from delays have generally demonstrated the wisdom of this painstaking care and expense.

One very good example of coal handling equipment is given in the illustration on this page, representing a boiler



A DOCK HOISTING AND CONVEYING PLANT, BUILT BY THE C. W. HUNT CO., NEW YORK

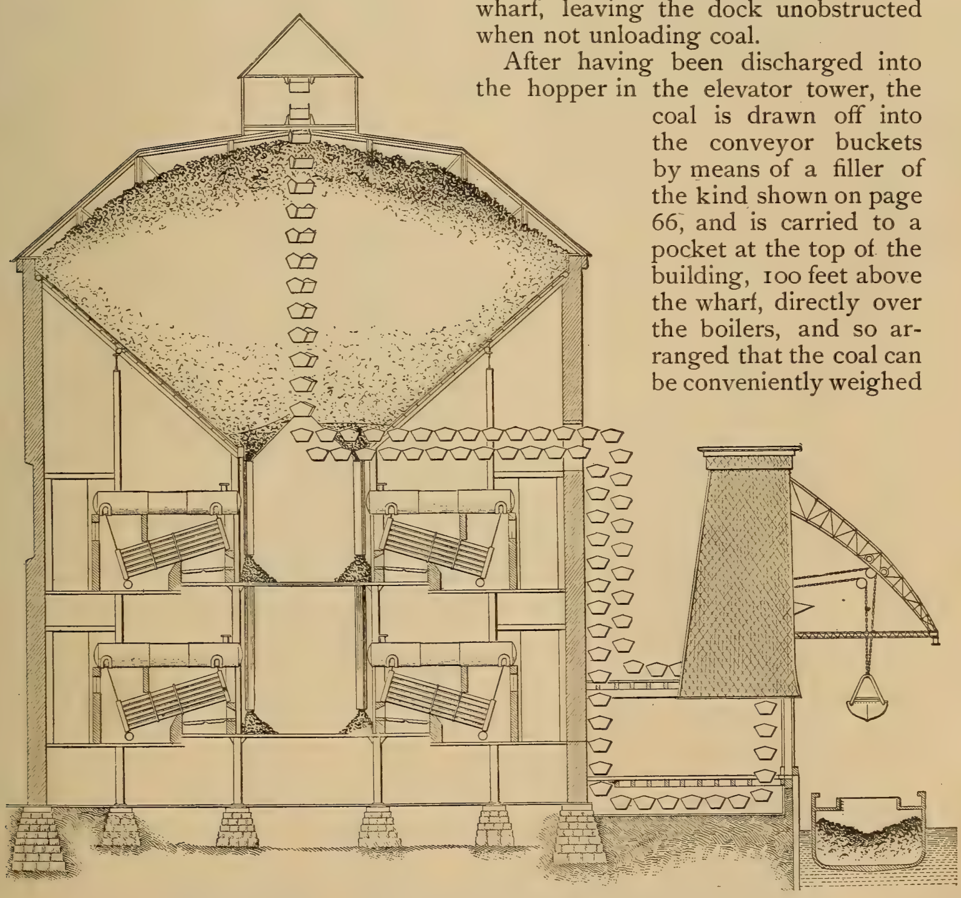
room interior of an electric light and power plant, fitted up with machinery from the works of the Jeffrey Manufacturing Company, of Columbus, O., U. S. A. The special conditions existing in this case were a power house on one side of a street, and a railroad switch on the other. Fuel, of necessity, had to be stored where the switch was located. Hoppers were built paralleling this switch, and into these the fuel was delivered from the cars. Thence it was fed to a modern drop flight conveyor which crossed the street in a tunnel, and this delivered the fuel to a continuous bucket elevator,—a type of elevator which is practically a series of continuous buckets or pans bolted to a wrought steel chain in their centres.

This elevator, in turn, delivered the fuel to a conveyor similar in construction to the one below, placed immediately over the boiler house hoppers which are constructed of steel plate and usually have a capacity of a day's consumption for the boilers which they feed. Gates in this conveyor trough, controlled by mechanism which is oper-

ated from the floor below, deliver the fuel to the boiler house hoppers. From the hoppers, spouts run to the mechanical stokers on the boilers, with valves inserted to control the flow of fuel. No supplementary labour is needed in the boiler room whatever. The handling capacity is thirty tons an hour and the whole operation is practically automatic from start to finish.

The problem of how to best handle coal, of course, varies with each new set of conditions. What may answer very well in one case, may be altogether unsatisfactory in another, making it necessary to carefully study the requirements in every instance. For hoisting coal from boats at a wharf the C. W. Hunt Company, of New York, have built a number of excellent plants, one of which is shown on this page. Although the coal, in this case, is received in vessels, it was necessary, in the event of failure of this source of supply, to provide means to receive it from wagons. Accordingly, the conveyor proper was carried under the street to receive coal from local dealers should this become necessary. The unloading from the boats alongside is accomplished by means of a steam shovel, operated by a double-cylinder rapid hoisting engine, contained in the tower, and taking steam from the main boilers. The parabolic steel booms which are shown on page 64, projecting over the hatch of the vessel, are pivoted on a vertical axis, so that they can be swung horizontally over the wharf, leaving the dock unobstructed when not unloading coal.

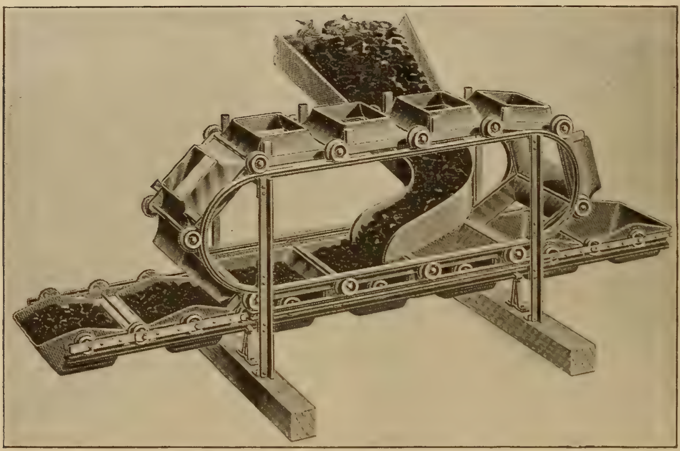
After having been discharged into the hopper in the elevator tower, the coal is drawn off into the conveyor buckets by means of a filler of the kind shown on page 66, and is carried to a pocket at the top of the building, 100 feet above the wharf, directly over the boilers, and so arranged that the coal can be conveniently weighed



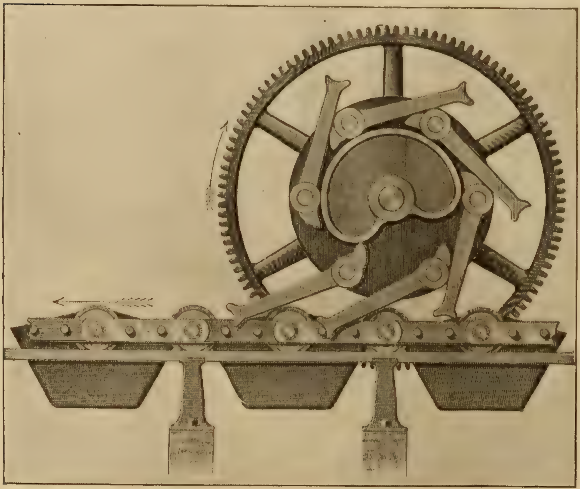
SECTIONAL VIEW OF A HUNT COAL HOISTING AND CONVEYING PLANT.

and spouted to either of the boiler room floors at a distance from the furnaces that is most convenient for hand firing.

The necessity for a special method of filling the buckets will be apparent when it is considered that the buckets swing freely on pivots, and might oscillate to a harmful extent or might be loaded on one side and remain at an angle throughout the trip. The loading is accomplished by the filler shown, so perfectly that it would not occur to an observer that there was any liability of the buckets swinging or of being unevenly loaded. The filler also guides the proper amount of material into each bucket as it passes, and prevents dust from reaching the joints of the chain or the bearings of the wheels, both of which can be kept thoroughly lubricated. A very interesting feature of the Hunt conveyor is found in the driv-



HUNT'S FILLER FOR CONVEYOR BUCKETS.



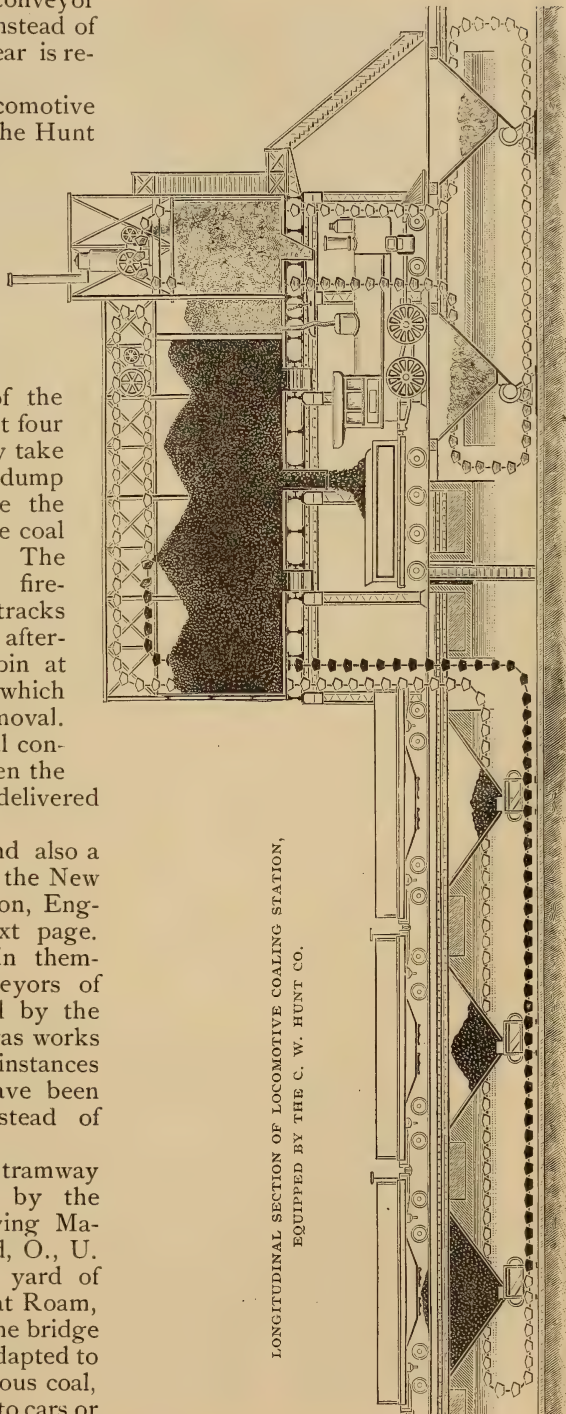
THE DRIVING MECHANISM OF A HUNT CONVEYOR.

ing method adopted, the conveyor chain being driven by pawls instead of by sprocket wheels, so that wear is reduced to a minimum.

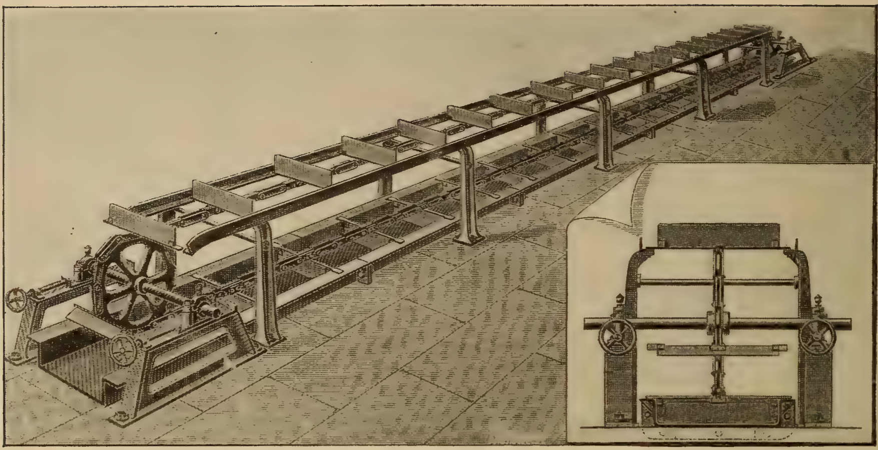
One of the prominent locomotive coaling stations equipped by the Hunt Company is shown in section on this page. The plan there adopted is to dump the coal from the cars into large hoppers below the tracks, and to elevate it, by a conveyor, to storage bins from which it is drawn into the locomotive tender, as required, through chutes. The arrangement of the chutes and hoppers is such that four locomotives can simultaneously take coal, sand and water, and dump ashes, and at the same time the conveyor is carrying both the coal and the ashes to the bins. The ashes are dumped from the fire-boxes into hoppers under the tracks where they are wet down, and afterwards carried to the storage bin at one end of the building from which they are drawn daily for removal. The sand is carried by the coal conveyor to a bin situated between the coal and ashes and thence is delivered to the locomotives.

A form of tray conveyor and also a push plate conveyor, built by the New Conveyor Company, of London, England, are shown on the next page. The illustrations there explain themselves. A great many conveyors of this type have been installed by the makers for retort houses in gas works and coal stores, and in some instances the push plate conveyors have been arranged with steel ropes instead of chains.

An example of a bridge tramway conveyor plant, turned out by the Brown Hoisting and Conveying Machine Company, of Cleveland, O., U. S. A., for the coal stocking yard of Messrs. Coxe Bros. & Co., at Roam, Pa., is shown on page 70. The bridge tramway system is especially adapted to the handling of soft or bituminous coal, either in taking it from a vessel to cars or the stock-pile, or *vice versa*, as the coal

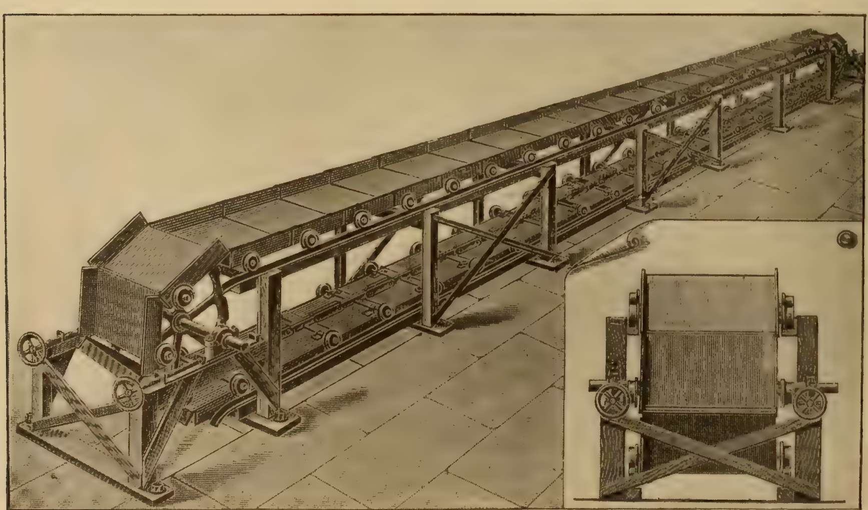


LONGITUDINAL SECTION OF LOCOMOTIVE COALING STATION,
EQUIPPED BY THE C. W. HUNT CO.



A PUSH PLATE CONVEYOR, MADE BY THE NEW CONVEYOR CO., LONDON.

can be lowered into a vessel or on board cars and dumped close to the bottom of these without breakage. Bridge tramways are generally built in plants of three or four bridges, two of the bridges being supported at their back ends upon one double back pier, and the other bridge or bridges being supported singly on a single back pier. An engine and boiler house is erected on the double back pier, and contains the boiler and three or four hoisting engines for the three or four bridges, as the case may be. The double back pier also supports, near its top, a covered platform, from which the operators can overlook the dock and control and operate the engines and hoisting machinery. Each bridge is supported in front by an independent pier, which permits the front to be skewed or moved sideways to suit the hatchways of a vessel without

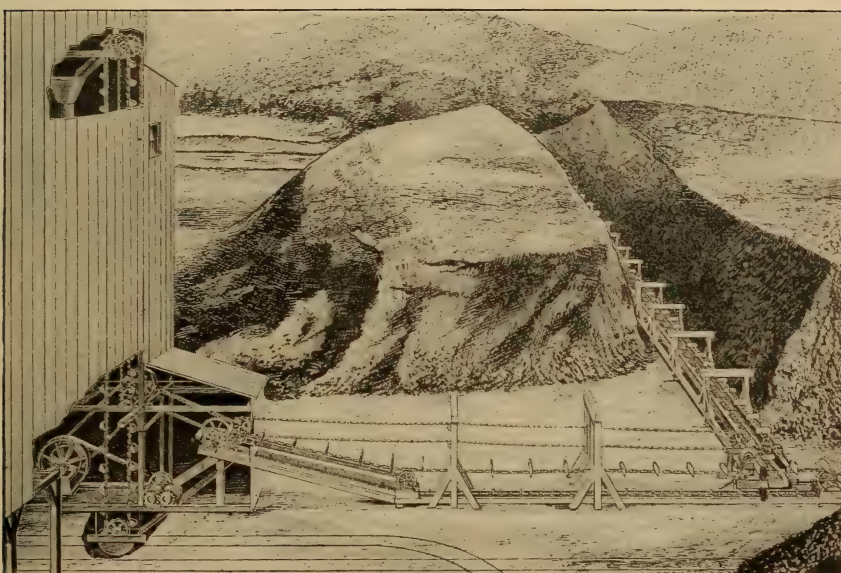


A TRAY CONVEYOR, MADE BY THE NEW CONVEYOR CO.

moving the rear end, the bridges being hung to the piers with hinged connections for this purpose. The front piers are mounted on wheels, and move on a track of a single line of rails ; the back piers are on wheels moving on a track of two rails. These machines hoist the buckets of coal from the vessel, convey it to any desired point on the tramway and automatically dump the material on the dock, or lower the bucket to the dock or cars below, as may be required. They will equally well reverse the process, *i. e.*, take the bucket from the dock or car, convey it to the vessel and lower and dump the contents into the hold, or take it from any point under the bridge and deliver it at any other point under the bridge.

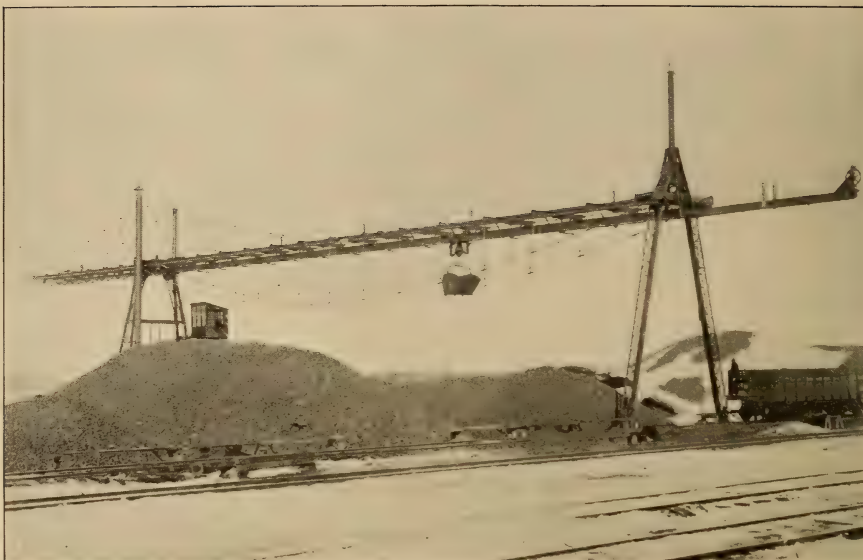
An example of cable-way conveying plant is given on page 71, which represents a Bleichert installation erected by the Trenton Iron Company, of Trenton, N. J., for the Royal Coal and Coke Company, of Prince, W. Va. The plant serves for carrying coal from the company's mine across the New river to the railroad, the difference in elevation between the terminal points being 820 feet, and the total length of the line amounting to 2800 feet. The line is located on the side of a steep mountain, and pitches from the landing station at an angle of about 30 degrees.

On pages 72, 73 and 74 finally are given illustrations of several conveying plants installed by the Link-Belt Engineering Company, of Philadelphia, Pa. The first of these shows some conveyors employed in working out culm banks in the anthracite regions of Pennsylvania. The culm, containing large quantities of small coal, is carried by the 475-foot conveyor shown, and an inclined conveyor, in turn, carries it to the washery shown at the right of the illustration. The first conveyor is fed at a point about midway of its length by another horizontal conveyor or reloader, which is swung against the base of the culm bank and follows it up as the working proceeds.



A CONVEYOR AND ELEVATOR, BUILT BY THE EXETER MACHINE WORKS, PITTSTON, PA., U. S. A.

The second illustration, on page 73, shows a coal conveyor designed to



A BRIDGE TRAMWAY CONVEYOR, BUILT BY THE BROWN HOISTING AND CONVEYING MACHINE CO., CLEVELAND, OHIO, U. S. A.

A MOVABLE COAL HOISTING AND CONVEYING APPARATUS, BUILT BY THE SAME COMPANY.

meet conditions which frequently occur, the coal being received from cars on a siding and delivered into the lantern of the building for further distribution. The third illustration, on page 74, of 40 feet. Then it is carried along horizontally for about 60 feet, and is finally delivered to a conveyor which, through gates, discharges it into the various bins of the storage house.

A CABLE-WAY CONVEYING PLANT, BUILT BY THE TRENTON IRON CO., TRENTON, N. J., U. S. A.

finally represents a plant installed for one of the big railroad companies. The coal, as received in a track hopper from the cars, is fed through a regulating gate to the combined elevator and conveyor, and is raised to a height Delivery to wagons for distribution is effected by gravity through chutes from the hoppered bins of the store house.

For stocking and reloading coal two varieties of conveyors are employed by the Dodge Coal Storage Company, of

Philadelphia, Pa. As described by Mr. J. M. Dodge some time ago before one of the engineering societies, one of these conveyors, known as the flying extension, consists of an endless chain, to which flights or scrapers are attached, forming a chain conveyor, at the lower end of which is a sprocket wheel situated under the railroad track. The other end passes around a traction wheel secured at the upper end of a pole, which is held in an upright position by suitable guys. Conveyors of this kind have been used in lengths of about 150 feet, with the upper end located from 50 to 75 feet above the ground.

The scrapers measure about 8 by 20 inches, and are placed at intervals of about 2 feet on the conveyor chain. There is no support for the lower strand of chain between the foot and the head wheels. The upper strand, however, is carried on idler wheels at intervals of 50 feet. These wheels are either suspended on wire cables or are supported by light trestle work if convenient.

The province of the flying extension conveyor is to take coal from a dump situated above its lower end and to convey it towards its head wheel, thus forming a pile of coal of conical shape with the apex under the lower strand of chain, and if the conveyor is fed until it has carried coal to its upper end, the apex will be directly under the head wheel, forming a pile, say, about 65 feet high and 300 feet across its base, and containing in the neighbourhood of 20,000 tons. The pile of coal so formed is in the best possible condition to be reloaded, as there need be no trestle work or other timber obstruction in it, excepting the already-mentioned pole. In the event of it being advisable to use the same apparatus at another place after its having built up

CONVEYOR BUILT BY THE LINK-BELT ENGINEERING CO., OF PHILADELPHIA, PA., U. S. A., FOR RE-WORKING CULM BANKS.

ANOTHER LINK-BELT ENGINEERING CO. CONVEYOR.

one pile, the only portion remaining in the pile would be the pole, costing a comparatively trifling sum.

For reloading the coal into cars after it has been stocked, a conveyor is used which is so constructed that it may be moved sideways toward the base of the pile, and kept running continuously while automatically attacking and conveying the coal toward the trestle from which it was originally dumped, and at which point it discharges the coal into an inclined conveyor which elevates it to a loading pocket. From this it is tapped into cars. The reloading conveyor is so constructed that it can be swung to the right or left, and is capable of operating on either side;

A LARGE RAILROAD CONVEYOR, INSTALLED BY THE LINK-BELT ENGINEERING CO.

consequently, by locating it between two flying extension conveyors, it would be able to reload the coal stocked by either of them. By means of these two types of conveyors, it is possible to store immense quantities of coal on vacant land, affording cheap storage capacity, and to inexpensively reload and deliver it when called for.

All the machinery shown in the preceding pages is typical of current practice, and the several illustrations demonstrate very clearly the extent to which labour-saving methods in the handling of coal have been developed. In how great a measure they may contribute to low cost of coal between the mine and the ultimate working point at the mouth of the furnace becomes apparent even without much study.

JEREMIAH HEAD.

PAST PRESIDENT OF THE BRITISH INSTITUTION OF MECHANICAL ENGINEERS.

FOR many years Mr. Jeremiah Head, whose portait is presented in this number, has ranked prominently in the engineering profession, and on both sides of the Atlantic his name is well known and identified in connection with many important engineering undertakings.

At an early age he was articled to Robert Stephenson, the celebrated engineer, and served his time at the well-known locomotive and marine-engine building works at Newcastle-on-Tyne, England, carried on by his employer and others. Later, he was promoted to a position on his civil

engineering staff. In 1856 he was entrusted with the design and supervised the construction of a large pair of compound condensing engines for driving the Priestgate Woollen Mills at Darlington, belonging to the firm of Henry Pease & Co. These engines were fitted with a parabolic governour controlled by an air cataract, and comprised several other specially devised details which were at that time novelties. They worked for about thirty-five years, when, the mill being burned down, they were replaced by others. The following year Mr. Head designed and supervised the building and erection of another large pair of engines of somewhat similar character for the paper mills of Messrs. Anandale & Co., of Shotley Bridge, near Durham.

A little later he was appointed resident engineer for the rebuilding of the iron bridge over the Wear at Sunderland, which occupied two years, and was Stephenson's last public work of any magnitude. He was then selected to co-operate with Mr. John Fowler, the well-known agricultural engineer, in bringing to perfection the steam plough with which that gentleman's name will always be associated, and in commencing the extensive works at Leeds, which became the principal seat of manufacture of them. The set of steam-ploughing apparatus which succeeded in gaining the much-coveted prize of £500 offered by the Royal Agricultural Society, and which was exhibited at the Chester Show in 1858, was mainly constructed at the Newcastle works, to the designs and under the supervision of Mr. Head.

In the year 1863, in conjunction with Mr. Theodore Fox, J. P., Mr. Head built large iron works at Middlesbrough, and carried them on until 1885, soon after which year they sold them, and dissolved partnership. Since then, Mr. Head, although still deeply interested in the Cleveland iron and steel industries, has devoted his time and personal energies almost exclusively to professional engineering. He has designed and supervised the carrying out of several iron and steel works plants, engines and boilers of considerable power and high efficiency, and coke and gas-making plants, etc. He has made numerous investigations, sometimes under an order of court, sometimes at the instance of private owners, into properties in litigation or otherwise in difficulties, and his reports have generally had the effect of indicating clearly the best course to pursue in order once again to reach smooth water.

He has visited most European countries, more particularly Spain, Norway and Sweden, as well as the United States, and he has made exhaustive reports on various properties, more especially iron, coal and manganese mines, and iron and steel works for English and foreign clients. He has frequently been retained as technical expert in law and arbitration cases connected with mechanical engineering and metallurgy, but still more often as sole arbitrator. In one of these cases he was agreed on mutually between the War Office and one of their contractors, and after a long investigation succeeded in settling all the points in dispute. In other cases he has been agreed to on both sides as referee for the settlement of wages questions between large employers and their workmen. Here, also, he has always succeeded in arriving at decisions which have secured the respect of both parties. As a valuer of technical and other properties Mr. Head has had large experience, the aggregate amount of what has passed through his hands in this way during the last few years reaching several millions of pounds.

As an author of scientific papers Mr. Head is well known. He has contributed valuable memoirs and addresses to the British Association, the Institution of Mechanical Engineers, the Iron and Steel Institute, the Cleveland Institute of Engineers, the Sheffield Technical School, and various other societies, as well as numerous leading and other articles to the current technical literature of the day. Among his more recent contributions may be

named his paper on "Cleveland Industries," read before the Institution of Mechanical Engineers, August, 1893; on "Mechanical Science as Exemplified in Nature," before the British Association, Section G., in September, 1893; on "Scandinavia as a Source of Iron Ore Supply," before the Iron and Steel Institute in May, 1894; and on "American Rail and Tramways," before the Cleveland Institution of Engineers in February, 1895. In 1875 he was made a member of the Institution of Civil Engineers, and shortly after, a Fellow of the Chemical Society.

In the year 1885, having long been a Member of Council, he was elected to the presidential chair of the Institution of Mechanical Engineers, and held that position for two years. In 1894, at the Nottingham meeting, he presided over Section G. (Mechanical Science) of the British Association for the Advancement of Science. He was the originator in 1864 of the Cleveland Institution of Engineers, a society which has had a marked effect in making Middlesbrough the recognized centre of the British iron and steel industries. He occupied the position of honourary secretary for three, and of president for other three years. Mr. Head is one of the original members of the Iron and Steel Institute; the treasurer and a member of the Board of Management of the British Iron Trade Association; and the same with regard to the Board of Conciliation and Arbitration of the North of England Manufactured Iron Trade. In January, 1894, Mr. Head found it necessary to move the headquarters of his consulting practice to London, and accordingly opened offices in Westminster in partnership with his son, Mr. A. P. Head.

Current Topics.

It is not long ago since a boiler was urged for sale with the special recommendation that upon every part of the interior an attendant, in cleaning it out, could readily lay his hands. Though it may be necessary thus to handle every part of the inside of the boiler in order to insure its perfect condition, there may be urged this fact, in behalf of those who prefer or who are compelled to use other forms, that their boilers go along quite satisfactorily year in and year out without this actual internal handling. If a boiler be run, or must be run, with water so bad that a periodical shoveling out is necessary,

and must be regarded as the only means of keeping it in good condition, then the hand visitation of every part may be looked upon as a necessity, and the possibility of accomplishing it as a great advantage. A worthier subject of study may, however, be found in the possibility of keeping boilers cleaner, both from soft mud and from harder incrusting materials, by blowing down at more frequent intervals than are common and usually supposed admissible.

INCRUSTATIONS are apt to be looked upon as things which cannot be prevented, and hence, can hardly be reduced by any means or by any improvement in management such as can be expected from an average attendant. This is by no means the exact truth, for the records of good boiler practice show clearly that the best results are often within the reach of men who will use the same care and as much of it in their boiler feeding and blowing as they are glad to give to the oiling and polishing of their engine parts. So long, too, as the best feed-water heaters can be had for so little money, doing their work with exhaust steam, the loss of heat done to blowing down can be safely permitted without any fear of loss greater than is liable to be encountered through this accumulation of incrustations.

THOSE who fit up and erect boilers have something to answer for in connection with this, in that they often put the blow-off valve in some hopelessly inaccessible place into which it is hardly expected that anyone will go except under absolute compulsion. Therefore, so long as this valve remains tolerably tight, and hence is likely to hold the water in the boiler, many attendants know little, and often care less, about the advantages due to its frequent use. Their sole anxiety is that the bar with which it was last screwed down was too short to render it certain that it will remain tight until they may feel it necessary to go that way again. The fixture, therefore, being inconvenient to use, is not used to the advantage or real profit which is so often practicable, and is sometimes a much needed element in the management of the whole apparatus.

ONE of the most perplexing problems that the mechanical engineer or the superintendent of a manufacturing establishment encounters, is the dovetailing of new buildings upon old ones so as to work in harmony with them, and at the same time introduce such improvements as may be necessary. Frequently, half a dozen buildings are erected on a large plot of ground, each building facing in a way that seems most convenient at the time, and without any particular reference to the others. When the establishment has grown so that the available ground area must be nearly covered over with buildings, and each one must, either by shafting or belting, be connected with its neighbour, or with some central source of power, then the trouble arising from lack of harmony in the original structures makes itself felt in a most aggravating manner. It seems, sometimes, as though trouble had been created on purpose by those who first erected the shops, so particularly uncompromising do the buildings appear. The moral, therefore, is that in putting up a shop, it is well to think a long way ahead, and to consider at least some of the most probable contingencies of the future.

THE first pair of horizontal turbines ever built, working on a common axis, was made the subject of an interesting note, presented a short time ago by Mr. Emile Geyelin before the Engineers' Club of Philadelphia, It appears that in the spring of 1854, a little over forty-one years ago, there came to the Brandywine, near Wilmington, Del., U. S. A., from Palitas, Mexico, Mr. James Prince, the owner of a cotton mill in Mexico. Mr. Prince informed his

friends on the Brandywine that he was on his way to Manchester, England, to order an overshot water-wheel 100 feet diameter, for which he expected to expend $25,000, or about £5000. Mr. Prince's friend, Mr. Riddell, presented him to Mr. Alexis DuPont, of gunpowder fame, and the latter, knowing the advantage of turbines as actually demonstrated in his own works by Mr. Geyelin, unhesitatingly recommended the use of turbines instead of the overshot wheels. The problem was certainly a bold one,—to build a 140 horse-power turbine under 160 feet fall. However, studying the subject and making the necessary calculations, Mr. Geyelin agreed to turn out a pair of horizontal axis turbines, connecting them to a countershaft by means of spur wheels, whereby the motion was transmitted, and a speed of 185 revolutions per minute attained, for which the charge was $2300, or about £460, or less than one-tenth of what Mr. Prince expected to spend in England. The turbines were 11 inches in diameter, and made 1850 revolutions per minute, and their performance in Mexico must have been highly satisfactory, as several similar orders were sent afterwards.

WITH all the disastrous steam pipe accidents that have occurred from what has become known as water hammer, the full extent of the strains which may be produced by this phenomenon is rarely appreciated. Some time ago, at one of the meetings of the American Society of Mechanical Engineers, Professor Thurston cited a case where steam was carried from a boiler room down the opposite wall and under the floor, a distance of several feet, and then up to the steam chest of the engine. In the U thus formed was placed a cock, to be opened for draining by the engineer whenever the engine was stopped, and to be closed when the engine was running. It happened that one morning the engineer was not in the room at seven o'clock, and his assistant came in and at once stepped to the throttle valve, which was set in the pipe lying against the wall, at the point where the steam entered the U on the way to the engine. The instant he opened the valve there was a crash; the cast-iron steam pipe was broken below the floor. He went below and found the engineer dead, having been killed by the exploding pipe. He had gone down to set up a joint which had probably been loosened by this very action. This fact illustrates either the force which water may exert when forced through a pipe by the impelling power of steam, or the forces that may be set in action by the sudden contraction of a moving mass of steam when coming in contact with a mass of cold water. Either action would have been sufficient for the result described.

ANOTHER instance was mentioned where the steam pipe was not sufficiently drained, and the water collected in the pipe and was carried over into the cylinder of the engine, wrecking it. Large stresses must be produced, and it would be interesting to observe how large these stresses are. No one has yet found a way of ascertaing them accurately. The fact that such accidents do occur, unquestionably due to the impact produced by the rapid condensation of steam on the surface of a pool of cold water, shows that these stresses must be enormously great. What may happen when a rapidly moving, heavy mass of solid water in full career strikes an obstruction we all know; but the hammering of steel in pipes produces a local strain probably quite as severe, perhaps even more serious. This second kind of strain is known to be enormously great, but how great can only be conjectured. Professor Thurston had occasion once to examine a quantity of pipe taken out of a heating system. He was informed that the pipes were defective, and was asked to examine them for the purpose of obtaining a report to secure from the makers a reduction of their cost and possibly damages. Many of the pipes were split through good welds and bad

welds, through solid iron even, and the only report he could make was that they were injured by water hammer.

A QUANTITY of the pipe was taken to the mill where it was made and the pressures which they would stand were measured, split and weakened as they were. In order to obtain a fair idea of the actual pressures that the pipes would sustain, a rubber packing was arranged on the inside of each pipe, a strip covering each crack from end to end, drilling a few holes along the crack, so that the strength of the pipe should not be affected, and to insure that sealing these joints should not affect the strength of the pipe. The bolts simply held the packing up against the crack on the inside, so as to seal it by the slight pressure of a line of small bolts, which were put in simply to hold the packing in place. Pipes arranged in this way, and tested in the hydraulic apparatus of the mill, carried all the way from 300 to 1000 lbs. pressure to the square inch, injured as they were. The conclusion was obvious. The water hammer to which they had been subjected must have been enormously in excess of these figures, representing the strength of the pipe after the crack had been made. These facts are more impressive than any possible examination, without actual measurement of these quantities, and reveal the intensities of the strains that occur, and the risks of danger which occur from allowing water to stand anywhere in a pipe. After water has once collected in a pipe, especially in steam pipes leading to engines of large size, there is no safe way of removing this danger except by simply shutting the steam off at once if it is moving in the pipe, or keeping the throttle shut if it is not moving ; then let the steam down and drain the pipe completely before steam is again put on.

AN excellent standard of skill and rapidity of workmanship is hinted at, even if it is not distinctly specified, in a notice posted in a well-kown machine shop to the effect that "every tool is required to be run to its full capacity." This at once sets a mark to which all concerned can look, namely, the result obtained by the best man who, in the course of a few weeks, may be employed to run the tool. Allowance must be made, and are, in every shop, for the difference in skill and faculty of contrivance existing among men of equal willingness and general capacity, but it is only by some means like these that a fair general standard can be set.

ONE of the most dangerous men in an engineering establishment that intends to make money is the fine mechanic who never knows where to stop putting on fine work. Such a man, left to himself, would scrape the bottom of an engine bed plate dead true, nickel plate every casting, and put a micrometer caliper on every piece in the engine. At the head of an establishment such a man would mean financial ruin. The difference between a business success and a business failure very often means knowing where to stop mechanical perfection. It ought to be an axiom in every establishment not to expend an unnecessary stroke on any piece of work. The fine work must stop short precisely at the point beyond which it is no longer needed. All this, of course, is easily said, but when a man has the moral courage to have this done, and to so regulate an establishment that this is practically accomplished on every machine, he becomes simply invaluable. Some of the best business successes have been made by men who had the courage to put the finest of work, fair work and common work all on the same piece of machinery. To know when and where to apply fine workmanship, it is necessary not only to consider the machine in itself and its working, but also to consider it as a merchantable article, subject to laws of trade, and to be treated as merchandise pure and simple. This way of looking at a machine is not only best for the producer, but for the buyer

also. It may be a pleasure to the purchaser to know that every leg of his big press, for example, is interchangeable and is fitted in place with scraped joints and polished bolts, but no manufacturer could afford to put such work on to the machine at the market rate, and the purchaser, again, could not afford to use such a press if he had to pay what it would actually cost. In short, the finest work on machines should be expended only when it is needed.

WITH the harping upon the subject of the boasted high efficiencies of all kinds of electrical machinery, a recent utterance by Professor Unwin is specially apropos, having been made in the course of one of his "Heat Engine" lectures at London, before the Institution of Civil Engineers. "In popular writings," said Professor Unwin, "nothing is commoner than to find the efficiency of electric machinery and of steam machinery contrasted to the great discredit of the latter. The dynamo, it is said, has an efficiency of 90 per cent. to 95 per cent., the steam engine an efficiency of only 10 per cent. What a barbarous machine, after all the labour of a century, the steam engine must be! The comparison is generally made by an electrical engineer, and the first reflection which occurs to one is that of all people the electrical engineer should be the last to abuse the steam engine, for whatever may be the case in some future century, at present the dynamo is absolutely dependent on the steam engine. Without the steam engine the dynamo would be a useless mass of metal and wire. But passing over the moral aspect of the question—the ingratitude of the electrical engineer—the comparison is an unfair one, and shows a want of apprehension of the important law of the motivity of heat, which is one of the two fundamental laws of thermo-dynamics. Heat energy is undirected, or mob energy. It lies in the nature of the terrestrial conditions in which use has to be made of it that only a fraction is converted into directed or mechanical energy. The task of the steam engine is to do its best with the fraction which is convertible, and in that point of view it is not an inefficient machine. The dynamo has a much easier task. Energy is supplied to it in its directed or wholly convertible form, and naturally in transforming one kind of directed energy into another kind of directed energy only a small fraction need be wasted."

EIGHT small electric ferryboats were put into service some time ago at Bergen, Norway, to replace the old inadequate row boat system, and afford interesting evidence of the growing appreciation of electric motor possibilities. The boats are about 26 feet long, of 6½-foot beam, and 2½-foot draught, and have a displacement of about 6 tons. They are built symmetrically fore and aft, and are provided with a screw and rudder at each end. The screws are on a common shaft, direct coupled to the motor, which is series-wound, weighs about 600 pounds, and is rated at 3 horse-power. It is placed in the middle of the boat under the flooring. The storage batteries are placed partly under the flooring and partly under the seats. The plates of each battery weigh about 3000 pounds, and have a capacity of about 20,000 watt-hours. The battery itself consists of 32 cells in series and weighs, altogether, 5280 pounds. The average speed, with a power of 2300 watts, is about 5 miles an hour. Each boat runs about 37½ miles a day, and about 1800 passengers, on the average, have been carried by the ferry each day. After the day's work is over the boats return to the charging station, where the accumulators are charged during the night, and the necessary cleaning is done and repairs made. The charging station is fitted with a compound portable steam engine, a dynamo of 30 horse-power and a suitable switchboard. During eight months of uninterrupted operation the plant is said to have proved excellent in every respect.

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THE EVOLUTION OF THE PORTABLE ENGINE.

By W. D. Wansbrough.

THE portable steam engine, or, to use the convenient continental expression, the "locomobile," is one of the most wide-spread and familiar products of British industry, and may, indeed, nowadays almost claim the honourable distinction, hitherto universally accorded to its big brother, the locomotive, of being the pioneer and herald of civilisation. For before the ponderous locomotive can wake the echoes of the primeval forest with its mighty roar, you may be sure that the tiny shriek of the portable engine,—sawing, grinding, pumping or what not—has been heard in the land. These engines are the drudges of the engineering world—mechanical children of Gideon—hewers of wood, and drawers of water.

Rough treatment and unskilled attendance are the common lot of the portable engine, and it may, at first sight, seem that its purpose would be answered by a combination of the simplest and most rudimentary form of steam engine with the cheapest possible boiler. And when it is further remembered, that in all probability, of all productions of human brains and fingers, you get more value for money in a portable engine than in any other article that it is possible to purchase, the arguments in favour of a strong, clumsy and roughly-finished machine, as the most likely to fulfill the conditions, would seem to be conclusive.

The direct contrary, however, is the fact. A specimen may be selected at random from almost any maker, large or small, and you will find, in the ordinary, every-day commercial portable engine, an example of careful and intelligent design, liberal proportions and good workmanship, which might be followed with advantage by makers of much more pretentious machinery. As a natural result, the demand has been enormous, and this, in turn, has led, in the cases of the leading makers, to an extraordinary development of their manufacturing appliances. The portable engine industry has, indeed, assumed very large proportions in Lincolnshire and the eastern counties of England; but for some inexplicable reason, attempts to introduce the manufacture into other parts of the country have rarely met with success.

The almost romantic history of the invention and development of the loco-

motive,—mainly the work of obscure mechanics or illiterate enthusiasts, at any rate in its early stages,—has been fully dealt with by a score of eminent

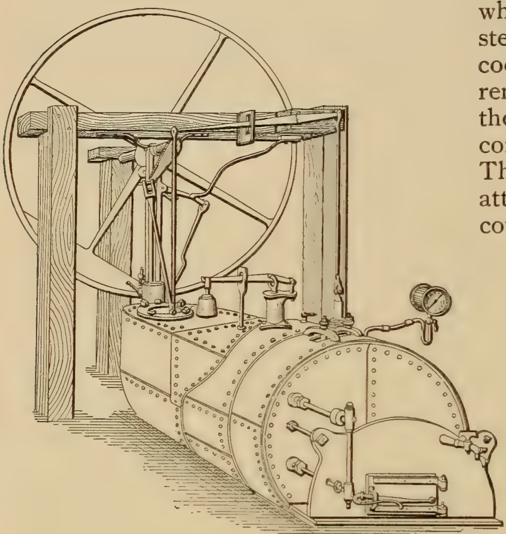


FIG. I.—TREVITHICK'S HIGH-PRESSURE ENGINE, 1811.

writers; the wider field of steam navigation and the progress of the marine engine has been thoroughly explored, and the results laid down permanently in stately volumes; and the same may be said of almost every variety of stationary steam engine. But the short and simple annals of the portable engine run great risk of slipping out of memory altogether, as one by one the witnesses who could speak from personal experience drop silently away, and direct evidence becomes increasingly difficult to obtain. The materials available are very scanty, consisting chiefly of the reports of the British Royal Agricultural Society, and the admirable articles in the principal engineering journals descriptive of the "Museum of Antiquities," brought together at that society's Kilburn meeting in 1879.

The first step in the direction of making engines portable was, undoubtedly, the plan of using steam of such a comparatively high pressure as to obviate the necessity of forming a vacuum, and having the cumbrous apparatus of the condenser. At a very early date—1727,—this appears to have occurred to Leupold, of Plunitz, who published in that year a Latin treatise, in which he describes a double-cylinder engine, wherein the admission and exit of the steam were regulated by a four-way cock, which alternately turned the current of steam from the one cylinder to the other, at the same time opening a communication with the atmosphere. The piston-rods appear to have been attached to beams for pumping. Of course, there was no rotary motion, and it is extremely doubtful whether this engine was ever really constructed.

In the year 1765, Smeaton, in his "Reports," describes a movable engine and boiler, but as this appears to have been a condensing engine with a cylinder of six feet stroke, it is hardly necessary to go into detail concerning it. The boiler, however, seems to have been self-contained and internally fired, and, therefore, has some claim to be considered portable. When the applicability of the steam engine to other purposes beside pumping became evident, several different methods were proposed for changing the reciprocating movement of the beam into

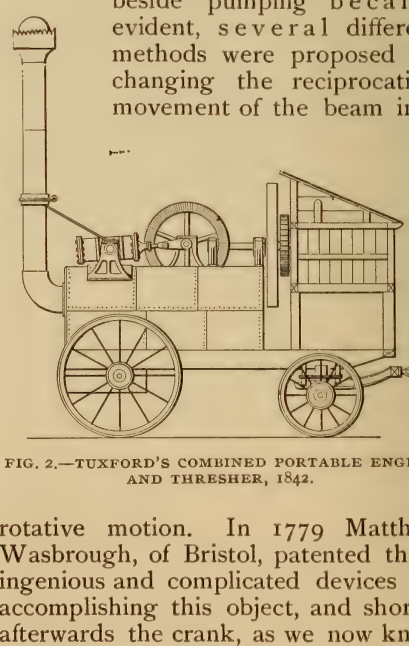


FIG. 2.—TUXFORD'S COMBINED PORTABLE ENGINE AND THRESHER, 1842.

rotative motion. In 1779 Matthew Wasbrough, of Bristol, patented three ingenious and complicated devices for accomplishing this object, and shortly afterwards the crank, as we now know

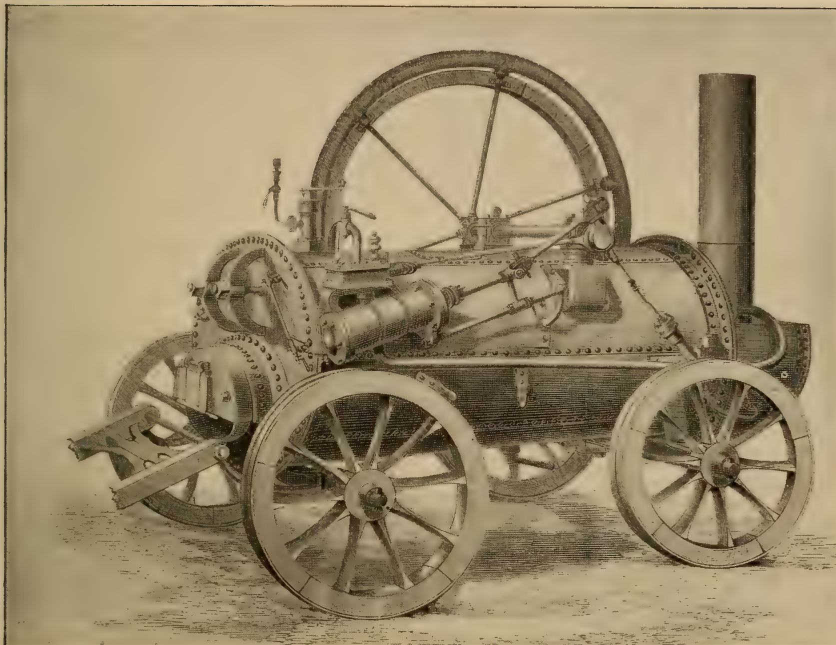


FIG. 3.—CAMBRIDGE'S ENGINE, 1843.

it, was applied to one of Wasbrough's engines by the purchaser, instead of the original ratchet motion; and for this a patent was granted to John Pickard in 1780. Watt also claimed to have invented the crank, but there is some doubt as to this.

The next important improvement in the history of the steam engine, which claims our attention as leading up to the possibility of the portable engine, is the invention by Murdoch, Watt's pupil, in 1785, of the slide valve; and, again, the first mention of a metallic piston packing appears to be that made in the application of Edward Cartwright for a patent, in 1797, previous pistons (and later ones also) having been packed with hemp.

In a patent granted to Matthew Murray in 1802, what appears to be really a portable engine is described, and even its suitability for agricultural purposes indicated. After a description of the details of the engine the patent-specification proceeds as follows:—"The parts so combined form a perfect engine, without requiring any fixture of wood or other kind of framing than the ground it stands upon; and is transferable without being taken to pieces. The motion of the flywheel gives circular power to any process or manufacture requiring circular motion, or for irrigating land, and for the various processes of agriculture."

Here we must break off for a moment to call attention to the singularly clear and explicit wording of Murray's claim. It was for an engine which is "transferable without being taken to pieces." At a period when steam engines, even of small power, were commonly incorporated into the structure of the house, which formed at once the frame-work and shelter of the machine, and were, consequently, about as portable as a parish church, this invention of Matthew Murray was a long step in our direction. But even a greater one was soon to be made by Richard Trevithick, who has been well called the apostle of high-pressure steam. Trevithick was born in 1771, his father being himself a

mining engineer of considerable eminence, who did much towards the improvement of the old atmospheric engine, and proved a rather formidable rival to Watt himself, in the county of Cornwall.

We cannot resist dwelling for a few

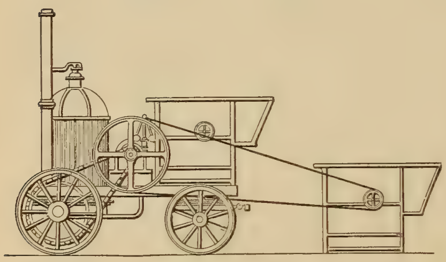


FIG. 4.—RANSOMES' COMBINED ENGINE AND THRESHER, 1841.

moments upon the inventions of this extraordinary and erratic genius. Listen to his own description of one of his engines:—"Chapell's engine had two cylinders and a double crank; the engines were fixed on the boiler; the piston-rod crosshead worked in guides fixed to the cylinder; connecting-rods went from the crossheads to the cranks. . . . Steam was turned on and off (*i. e.*, was admitted to each

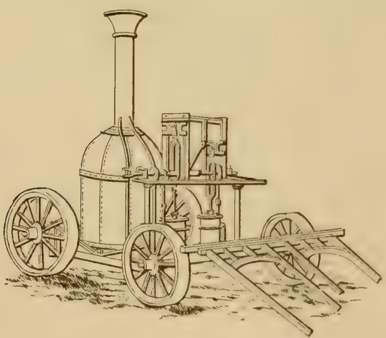


FIG. 5.—DEAN'S ENGINE, 1844.

end of the cylinders alternately) by a four-way cock." This engine, it seems, was furnished with a blast-pipe, but whether this was used to cause an artificial draught, does not appear. At any rate, it is described as "puffing so loudly that it could be heard for miles." In the account given of another of Trevithick's engines about the same period, however, it is explicitly stated that "the steam puffed up the chimney." The term "blast-pipe" was then unknown to describe the thing just brought into use. But the words, "the steam continued to rise the whole of the time it worked, until it was obliged to stop and put a cock into the mouth of the discharging pipe, to allow some of the blast steam to escape into the feed-warmer," prove the invention of the blast-pipe with its regulating cock and transmission of heat from surplus steam into the feed-water, to have been fully understood by Trevithick.

It seems difficult to believe that the description just quoted was written in the year 1802, at a time when Cornish engines on Watt's system were still working with boilers wholly or partially of stone, and engines dependent in most cases upon the masonry and walls of the engine house for the connection between the beam and the cylinder. Trevithick's engines were, moreover, direct-acting, so that we have, at this early date, the essentials of the portable engine,—high pressure, direct action and forced draught. The boiler appears to have been of cast iron, cylindrical, with a single wrought-iron tube passing through it, quite independent of brickwork foundations or setting, and the engine was attached to the boiler. The pressure would seem to have been about 30 lbs. per square inch.

These high-pressure engines were vehemently opposed by Boulton & Watt, who tried to get an act of parliament to prevent the construction of any more of them on the plea that the lives of the public were endangered. One of Trevithick's engines, built in 1811 for Sir Christopher Hawkins, was a prominent exhibit at the Royal Agricultural show at Kilburn in 1879. It was taken from work where it had been intermittently in use for sixty-eight years, and was to be again put into steam on its return.

It is to be feared that no modern portable engine is likely to enjoy such an extended term of life as this venerable machine has done. In the "Life

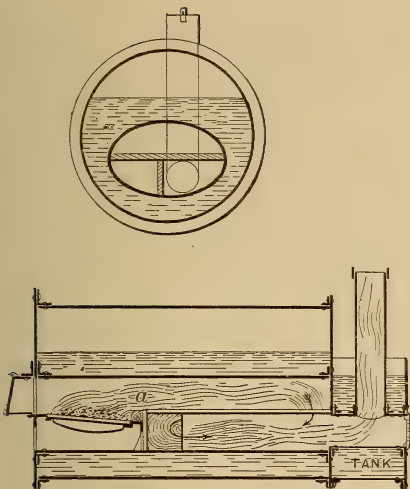


FIG. 6.—CAMBRIDGE'S BOILER, 1867.

of Trevithick" there are many other instances of the extraordinary length of time that these engines have been kept at work. In 1812 Trevithick was in a position to advertise publicly that he was prepared to make and supply portable steam engines for agricultural purposes, mounted on wheels, and weighing 15 cwt., at a price of 60 guineas. It is necessary to resist the temptation of lingering among the memoirs of Richard Trevithick, one of the most original and daring inventors who ever drew breath. His high-pressure engine, condemned by Watt as dangerous and wasteful, gave to the small consumer, for the first time, a possibility of having steam power upon his own premises at something like a moderate cost.

Trevithick's labours in connection with the locomotive engine, the screw propeller, steam ploughing and digging, and steam traction on common roads do not concern us just now, but as an encouragement to future inventors a short extract from the closing pages of his "Life," written by his son, Mr. Francis Trevithick may be of service. Trevithick died at Dartford, in Kent, on April 22, 1833. He was penniless, without a relative by him in his last illness, and for the last offices of kindness was indebted to some who had been losers by his schemes. The mechanics from the works of Messrs. Hall were the bearers and mourners at his funeral, and at their expense night-watchers remained by the grave to prevent body-snatching, then frequent in the neighbourhood. His grave was among those of the poor, buried by charity, and no stone or mark distinguishes it from its neighbours.

During the next twenty or thirty years comparatively little progress was made with the portable engine. The impetus given by Trevithick to its manufacture did not, for some reason or other, continue long. It is probable

FIG. 7.—MESSRS. HORNSBY & SONS' ENGINE, 1848.

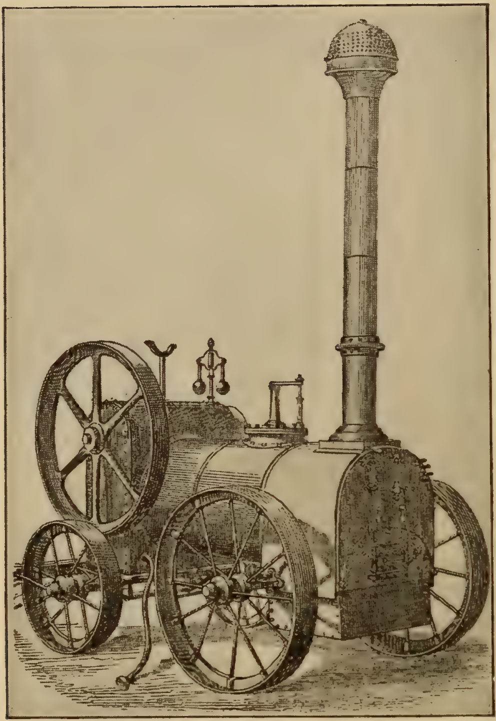


FIG. 8.—TUXFORD'S STEEPLE ENGINE, 1850.

thus, after a few engines had been made here and there, at irregular intervals, the industry appears to have died out altogether.

Fixed condensing engines seem, after this, to have been used to some extent for agricultural purposes, chiefly in Scotland, where fixed thrashing machines are still employed to a much larger extent than in England; but we hear hardly anything further of anything approaching the portable engine until 1839,—the date of the establishment of the Royal Agricultural Society. In that year Messrs. Tuxford, of Bolton, designed the curious machine shown in Fig. 2. This was finished in 1842, and set to work with satisfactory results. It will be seen that the flywheel shaft runs at right angles to the crankshaft, driven by bevel gearing, and, in its turn, drives the drum shaft of the thrasher by spur gearing. The cylinder

that an explanation of this may be found in the disturbed state of the country during this period, and the high price of corn, which, combined with the growing dislike to machinery, as evidenced by the continual rioting and machine breaking in the manufacturing districts, would all operate to discourage the use of steam engines on the farm. A farmer in those days, employing machinery to any extent to do the work of men's hands, would be very likely to be reminded, by blazing ricks and maimed cattle, that there were thousands of starving labourers whom he would do well to employ, instead of adding to the distress by throwing more men out of work.

The business of making engines after Trevithick's designs was chiefly scattered among small foundries, such as would be established for the manufacture of ploughs and the smaller class of agricultural implements. No one firm took the lead in the matter, and

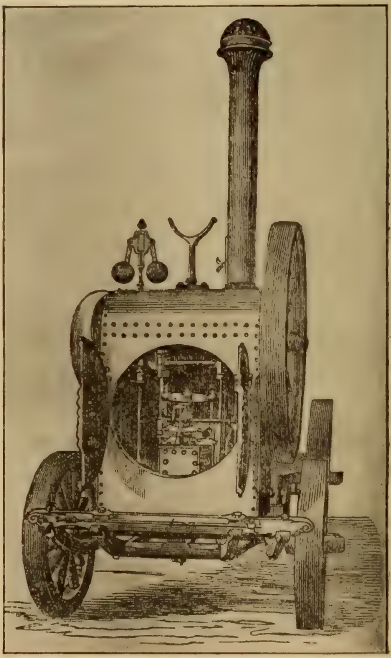


FIG. 9.—AN END VIEW OF TUXFORD'S STEEPLE ENGINE.

is oscillating and works the valve by its own motion. The fire door is at the rear end, and the oval flue of the boiler returns to the chimney at the same end. A copper water heater, using exhaust steam, forms part of the equipment. The engine was rated at 6 horse-power and the total weight, including the thrasher, was 3¼ tons. Within a twelvemonth from the trial of this engine, Messrs. Tuxford turned out six engines of this class, and afterward about twelve more of the same kind, after which they found it better to separate the engine from the thrashing machine.

In 1841, the Royal Agricultural Society held their meeting at Liverpool, where an engine upon wheels was exhibited for the first time, and with this the history of the modern portable engine may be said to commence. The engine was a rotary disc engine constructed by Messrs. Ransomes & Sims, of Ipswich, under the patent of Mr. Henry Davies, of Birmingham. As will be seen from Fig. 4, the engine was mounted upon four wheels, and was self-propelling, the power being transmitted to the hind axle by means of a pitch-chain. Upon the same platform was carried the thrasher, which, when at work, was dismounted, and driven by a belt from the flywheel of the engine.

In the report of the judges it is stated to the credit of this machine that "it has no beam, flywheel, parallel motion, guide rods, condenser, air-pump, or other intricate mechanism." With the exception of the flywheel, this is all undeniably true, as a single glance will show, and, encouraged by this eulogy, a company was formed at Birmingham for introducing it on a large scale; but, as is sometimes the case even now, the company soon got into difficulties, and we hear no more of the disc engine. The work done by this engine was estimated at 5 horse-power, the quantity of water evaporated per hour, at 36 gallons, and the consumption of coke as 56 lbs. According to these figures, the steam used per horse-power was 72 lbs. per hour, and the evaporation efficiency of the boiler was 6.4 lbs. of water per lb. of coke,—a result which shows that the boiler was of much greater efficiency than the engine.

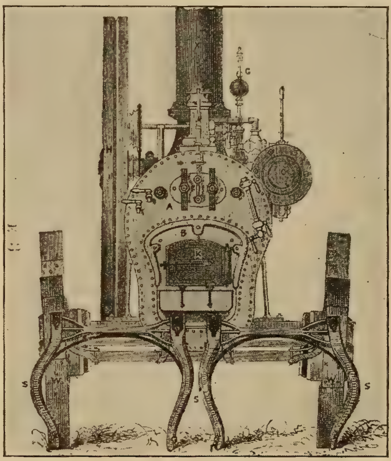


FIG. 10.—GARRETT'S ENGINE, 1851.

It is perhaps needless to remark that at this date, and for many years to come, the steam engine trials of the Royal Agricultural Society were not by any means the models of painstaking accuracy that they have become in recent years, but enough was elicited

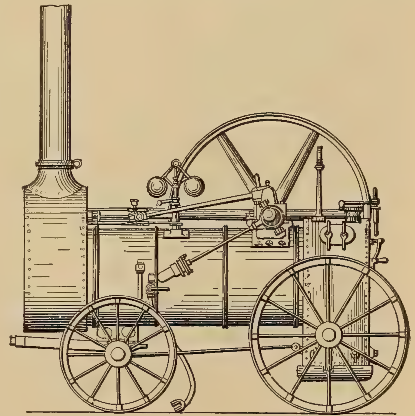


FIG. 11.—MESSRS. CLAYTON & SHUTTLEWORTH'S ENGINE WITH ENCLOSED CYLINDER, 1853.

from the results at this trial to show a very considerable saving to the farmer over the system of thrashing by hand.

The fact of the very high commenda-

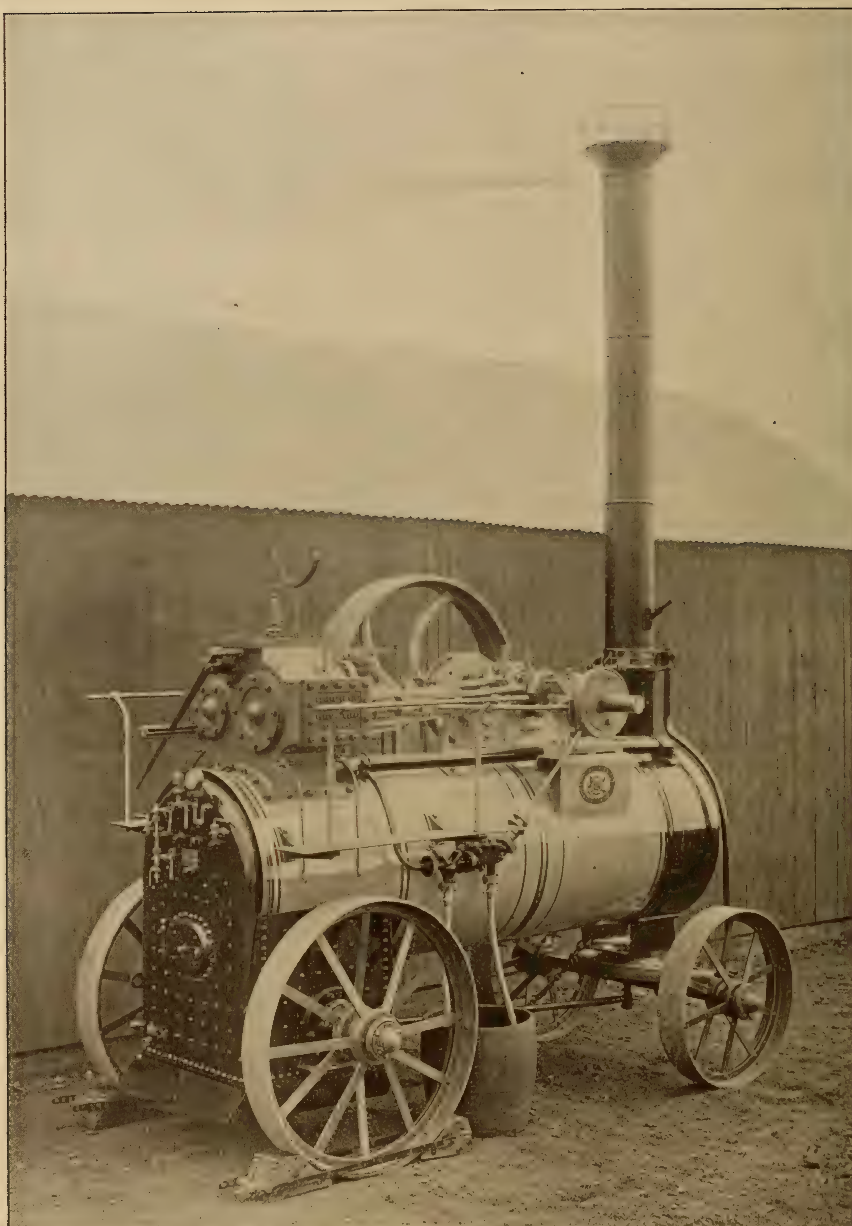


FIG. 12.—COMPOUND PORTABLE ENGINE WITH AUTOMATIC EXPANSION GOVERNOUR, BUILT BY MESSRS. RICHARD GARRETT, & SONS, LEISTON, ENGLAND.

tion of the engine by the Royal Agricultural Society did not, however, in the year 1841, remove the prejudice entertained by farmers against the use of steam-driven machinery in rick-yards, and the consequence was that Messrs. Ransomes' machine had to be brought back from Liverpool, and was ultimately separated, the thrasher going to one purchaser and the engine to another.

For some years after this, the exhibition of portable engines at the Society's shows seems to have been mainly in the hands of two makers, whose names, we believe, have long since disappeared from the list of manufacturing engineers. These were Mr. Alexander Dean, of Birmingham, and Mr. W. Cambridge, of Market Lavington, near Devizes. Mr. Dean is said to have made what may be termed a steeple-engine in 1841. This he exhibited at Bristol in the following year. He had for competitors the Mr. Cambridge just mentioned, with a portable engine having an oscillating cylinder, and Messrs. Ransomes, of Ipswich, with a modification of their combined engine and thrasher. In this year also Messrs. Clayton & Shuttleworth, of Lincoln, began to make portable engines, their output being two for the year.

At the Society's meeting at Derby in 1843, three portable engines were shown by Dean and by Cambridge; and in reference to this the judges announced in their report, with great complacency, that "the manufacture and use of travelling steam engines has now become a systematic business." It must not be forgotten that these were very far from being the spick-and-span machines now associated with the title of portable engine. Cambridge's was probably a vertical engine with the cylinder immersed in a cylindrical boiler with a return flue, but no authentic description exists of it. Dean's engine was vertical, with a dome-topped boiler and a rather ingenious arrangement of engine. The cylinder stood upright upon the bed plate, and the crank was carried overhead in a kind of square frame with pillars. Guides were cast upon the sides of the cylinder, having sliding blocks connected by an arched crosshead with the piston rod. The connecting rod was of the forked type,—very much so,—being wide enough in

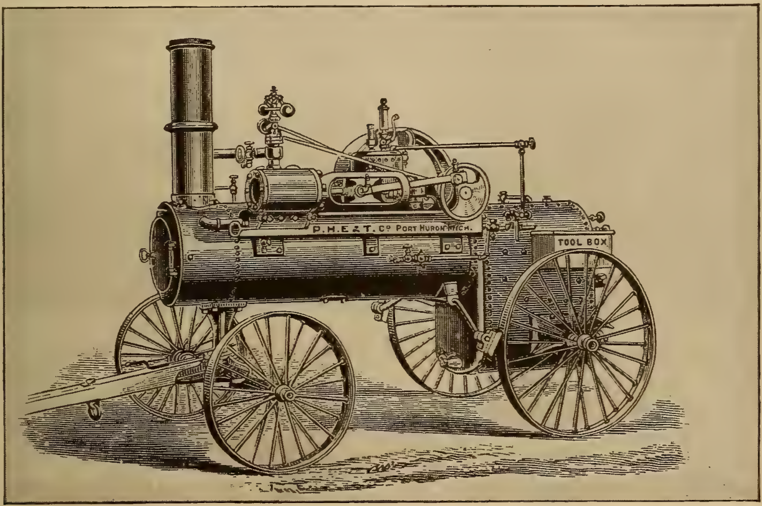


FIG. 13.—PORTABLE ENGINE, BUILT BY THE PORT HURON ENGINE AND THRESHER CO., PORT HURON, MICH., U. S. A.

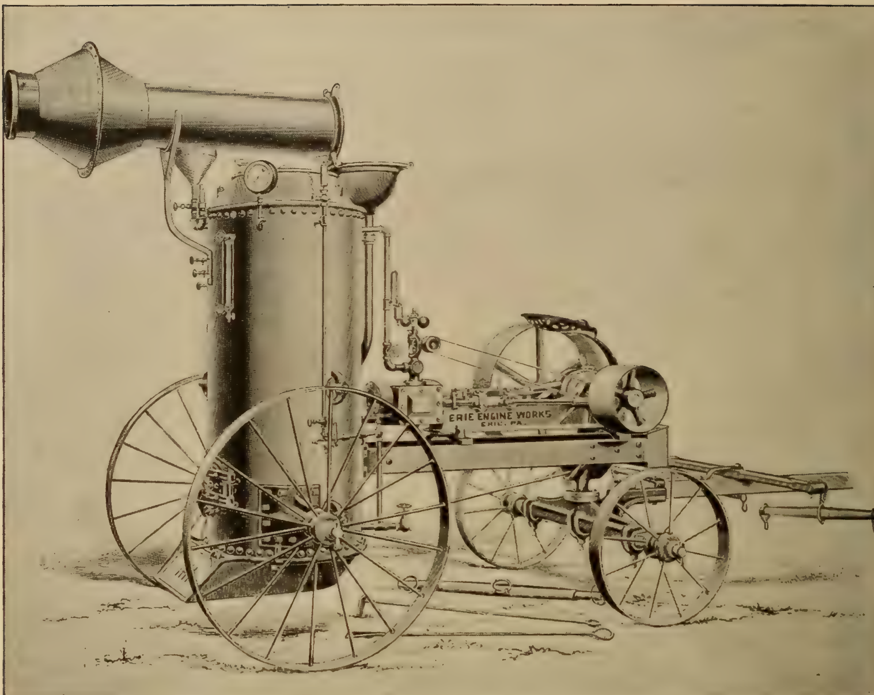


FIG. 14.—ENGINE BUILT BY THE ERIE ENGINE WORKS, ERIE, PA., U. S. A.

the fork to embrace the arched cross-head just mentioned. This made an exceedingly compact engine, the crank only just clearing the top of the cross-head.

In the year following,—1844,—the show was held at Southampton, with our friends Dean and Cambridge again as sole competitors as regards portable engines; but neither of these makers seems to have produced a very satisfactory engine. Dean's, which is the one shown in Fig. 5, was pronounced by the judges "not only inefficient, but highly dangerous;" while Cambridge's engine is stated, on the same authority, to have "consumed twice as much fuel as had been guaranteed by the maker." Evidently these judges were men of few words, but nevertheless they awarded a prize of £5 to Cambridge, while Dean, we suppose, considered himself "highly commended." Next year, however, the indefatigable Dean again competed with the inseparable Cambridge, and with such success that he was awarded the first prize of £10, his rival carrying off the second prize of £5.

An idea seems to have been prevalent at this time that the simpler in character the engine, the better it was adapted for use on the farm; and a year or two later this found expression in a statement by the engineer of the Royal Agricultural Society to the effect that "no engine intended for farm purposes should have a single superfluous part." A degree of simplicity, almost amounting to rudeness, was insisted upon in the endeavour to obtain an engine suited to the comprehension of the farm labourer; and it is very probable that many obvious improvements were sacrificed by the makers, with the view of recommending their particular engines to the favourable notice of the judges, as being "devoid of complication." Economy of fuel appears to have been quite a secondary matter, safety being

the first consideration, and it is probable that this mistaken idea on the part of the society did much to retard improvement.

About this time Messrs. Clayton & Shuttleworth made what appears to have been the first portable engine with horizontal cylinders on the top of the boiler, the crankshaft being geared by a wheel and pinion to a second shaft upon which the flywheel was fixed, making three revolutions for one of the crank, the whole being fixed upon a wooden frame. This was a distinct advance upon previous practice, the cylinders having been before almost always placed vertically. Cambridge, for example, went to considerable trouble to get over the difficulty of placing a vertical engine upon the top of a horizontal boiler, by sinking the cylinder into the boiler, and adopting an arrangement sometimes used in marine practice, consisting of two piston-rods, carrying between them a bent crosshead, which projected downwards into a deeply recessed top cylinder cover.

At the Newcastle-upon-Tyne meeting in 1846, Mr. Cambridge was the sole exhibitor of a portable engine, the locality being probably too remote for other makers to incur the expense of sending their engines for exhibition. This engine seems to have been constructed from the following recipe :—"Take a small pillar letter-box, bore out the lower part to fit a piston, and apply a slide valve and bottom cover ; put a crankshaft through near the closed top, with the crank inside ; couple it to the piston by a connecting-

FIG. 15.—A STRAW BURNING PORTABE ENGINE, BUILT BY MESSRS. RICHARD GARRETT & SONS, LEISTON, ENGLAND.

rod. Fill the space above the piston (which is single-acting) with exhaust steam, and immerse the whole in the boiler as far it will go. Boil till further notice.'' Had Mr. Cambridge made this engine with only two or three cylinders instead of one, it would have borne a remarkable likeness to some recent high-speed engines, and some modern patents would have been anticipated.

At the Northampton show in 1847, seven makers competed for a prize of £50. The award fell to Cambridge, who certainly deserved it, if only for his perseverance. His engine now assumed another of its protean forms, and is shown in Fig. 3, which was reproduced from a photograph taken at the Kilburn show of 1879, at which this identical engine was exhibited. The boiler is shown in Fig. 6, and consisted of a plain cylinder, with an oval flue running through it, divided from the bridge onwards into three longitudinal compartments. The products of combustion traversed this distance three times before escaping to the chimney, the lower part of which was immersed in a tank which formed the feedwater heater.

It appears that during the trial this engine was worked at 68 lbs. pressure, a very high one at that time, and at a speed of no less than 250 revolutions per minute. Mr. Cambridge was thus somewhat in advance of his time. As usual, objections and protests were lodged, but the engine was tested again before a special committee, at a more moderate speed and lower pressure, with the result that the award of the judges was confirmed. Unfortunately, however, the engine now before us does not appear to have come out by any means well, as regards either fuel-consumption or first cost, compared with Trevithick's engine of 1811; but the tests in either case, available for comparison, are not perhaps as precise as some which have taken place in later years. For example, the competitive trials at the Northampton meeting were conducted thus:—The engines were all placed in a row, each one with its thrashing-machine coupled up to it. A certain number of sheaves to be thrashed was given out to each one; at a given signal the series was started, and the first to finish thrashing was declared the winner. The duration of the trial was only eight or ten minutes.

Cambridge was again closely followed

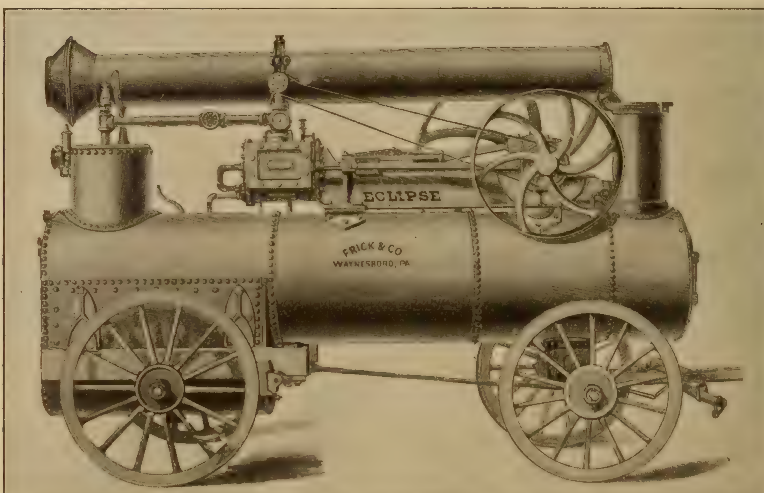


FIG. 16.—PORTABLE ENGINE BUILT BY THE FRICK CO., WAYNESBORO, PA., U. S. A.

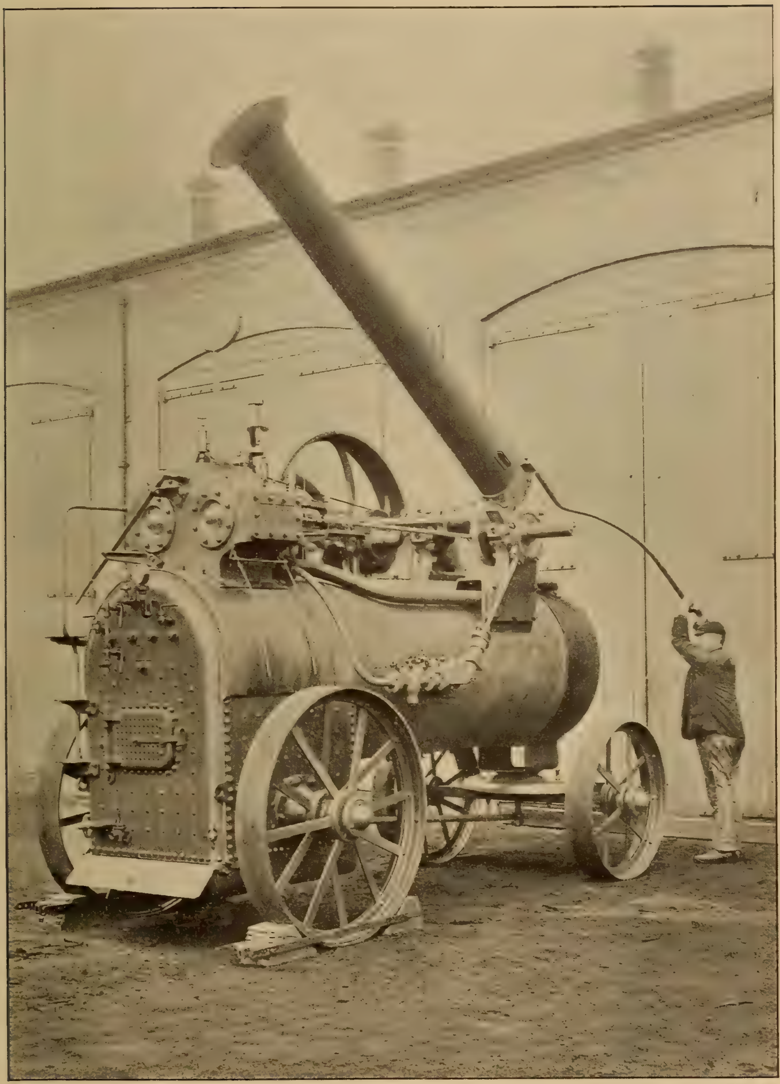


FIG. 17.—DOUBLE-CYLINDER, NON-COMPOUND ENGINE, BUILT BY MESSRS. RICHARD GARRETT & SONS, LEISTON, ENGLAND.

by his old rival, Dean (now Ryland and Dean). Messrs. Hornsby, of Grantham, were also among the exhibitors, and there was an engine there by Mr. Ogg, of Northampton, which deserves notice in passing. It was a double-cylinder engine of 5 horse-power, and had a locomotive-type boiler, feed-water heater, expansion valves and other modern improvements, which make it a matter for wonder that it did not take a better place in the experiments. It came out fourth. Its weight was about 2½ tons.

The use of double-cylinder engines was shortly afterwards expressly discouraged by the Royal Agricultural Society, on the ground that "two cylinders are not necessary for agricultural purposes; they make the engine more expensive;

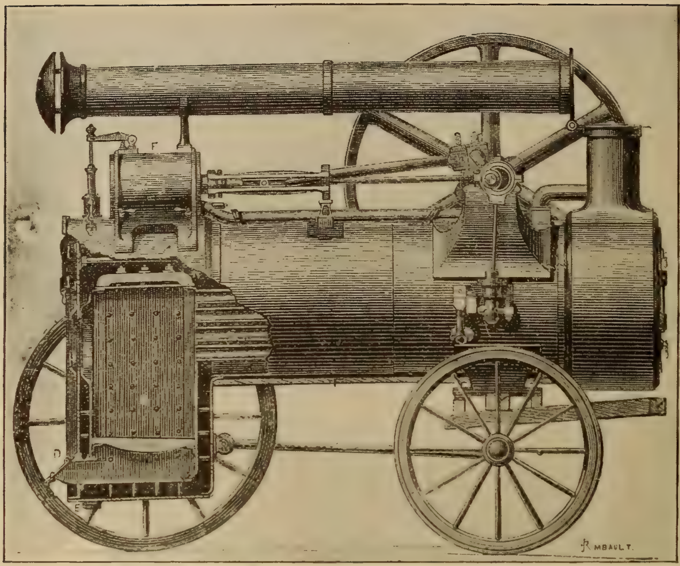


FIG. 18.—MESSRS. ROBEY & SCOTT'S ENGINE, 1861.

there are more parts to be kept in repair, and more attention is required to work them,"—all of which is profound truth to this day.

In Fig. 7, reproduced from the London *Engineer*, is shown an engine exhibited by Messrs. Hornsby, of Grantham, at the York meeting in 1848, where it was successful in carrying off the first prize of £50. The engine was lent by its owner as a contribution to the "Museum of Antiquities," at Kilburn in 1879. It will be noticed that the firebox is circular; the piston-rod is prolonged, and passes through a stem guide, with a long, forked connecting-rod. The steam-ports are short, one at each end of the cylinder face, with the exhaust port near to one of them. A hollow slide-valve, nearly as long as the cylinder, allows the exhaust steam to pass through it from the further port into the exhaust-opening. The cylinder was 10 inches in diameter and of 14 inches stroke; and the engine is recorded as having run against a 6 horse-power load with a consumption of 7 lbs. of coal per horse-power per hour. This, however, is probably an error. The same, or a similar, engine consumed 14.2 lbs. of coal per horse-power at the Norwich trials in the following year. Messrs. Hornsby subse-

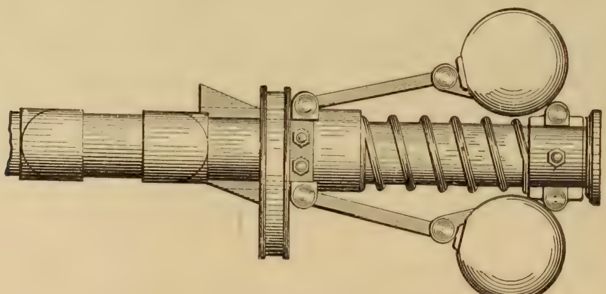


FIG. 19.—THE ROBEY CRANKSHAFT GOVERNOUR, 1869.

quently made this class of engine with an oval trunk working through the front cylinder cover and one of these the writer assisted to place upon a new boiler at Messrs. Hornsby's works at Grantham in the year 1872.

The judges at the Exeter show in 1850 mention that Messrs. Clayton & Shuttleworth's engine, there exhibited, had the steam pipe carried through the exhaust pipe, the latter itself passing through the boiler. As we shall have something to say about inside exhaust pipes shortly, we shall not comment further upon this remarkable arrangement of a doubly steam-jacketed exhaust pipe.

Very shortly after this we find nearly all the principal makers turning to the modern type of portable engine, with the ordinary locomotive boiler, and a single horizontal cylinder upon top of it. There is a statement in *Engineering*, in its account of the Kilburn show, that the first maker of engines of the now universally accepted pattern was Mr. Richard Bach, of Birmingham. There were, of course, exceptions—for

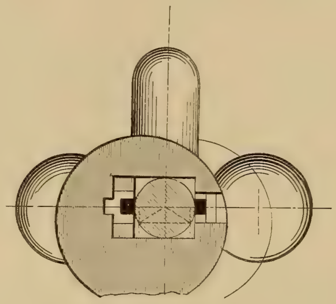


FIG. 20.—END VIEW OF THE ROBEY GOVERNOUR.

instance, the steeple engine of Messrs. Tuxford, which they exhibited at Exeter for the first time in 1850, and which they continued to manufacture for many years afterward. The engine itself, shown in Figs. 8 and 9, is contained in

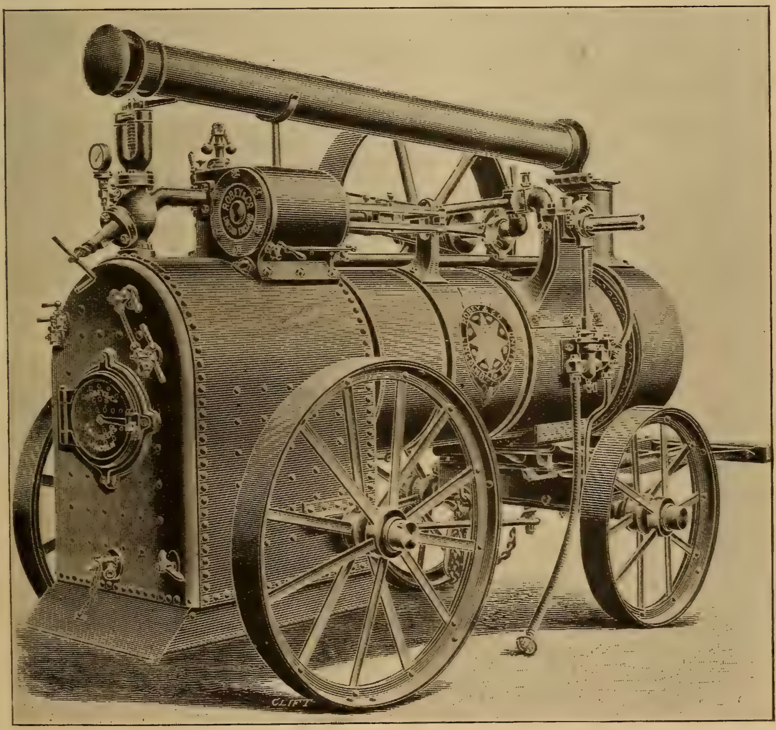


FIG. 21.—A SINGLE-CYLINDER ROBEY ENGINE.

an iron housing at the end of the boiler furthest from the firebox. The cylinder is placed vertically, the piston rod carrying a short beam or crosshead, from the ends of which a pair of rods descend, having guide blocks attached to their lower ends, sliding in guides formed in the sides of the cylinder itself. From these blocks a couple of connecting rods rise to a very wide crank, placed just above the cylinder. The boiler has a flat flue leading to an internal smokebox at the engine-end of the boiler ; from this, tubes return to the chimney over the firebox. In later engines by the same firm, this arrangement was reversed ; the tubes passed from the firebox in the ordinary way, and a flat flue over them returned to the chimney.

In 1851, at the Crystal Palace trials, in Hyde Park, London, in connection with the great International Exhibition, eleven makers entered engines for competition, the first prize being awarded to Messrs. Hornsby, of Grantham. The following table, extracted from the Juror's Report, gives the comparative efficiencies of the engines reported upon :

Maker.	Nominal H. P.	Coal per H. P. per Hour.
Hornsby	6	6.73 lbs.
Tuxford	6	7.46 "
Clayton	6	6.63 "
Garrett	5	8.65 "
Barrett	4½	9.20 "
Tuxford	4	10.85 "
Cabron	9	12.48 "
Burrell	6	13.10 "
Butlin	4½	14.71 "
Hensman	4	18.75 "
Roe	4	25.8 "

It is probable that the performance ot Messrs. Roe's engine in the way of coal consumption has never been surpassed by any other maker at a Royal Show trial ; but this record was completely eclipsed by the same firm at the Lewes meeting in the following year, when their engine is stated to have achieved the colossal result of 93.9 lbs. of coal per horse-power per hour. Messrs. Garrett's engine, the fourth in the list, is shown in Fig. 10. It is described as a "light, strong, portable, engine with an external horizontal cylinder."

The well-known inside cylinder engine of Messrs. Clayton & Shuttle-

FIG. 22.—ENGINE WITH STRAW BURNING ATTACHMENT, BUILT BY MESSRS. E. R. & F. TURNER, IPSWICH, ENGLAND.

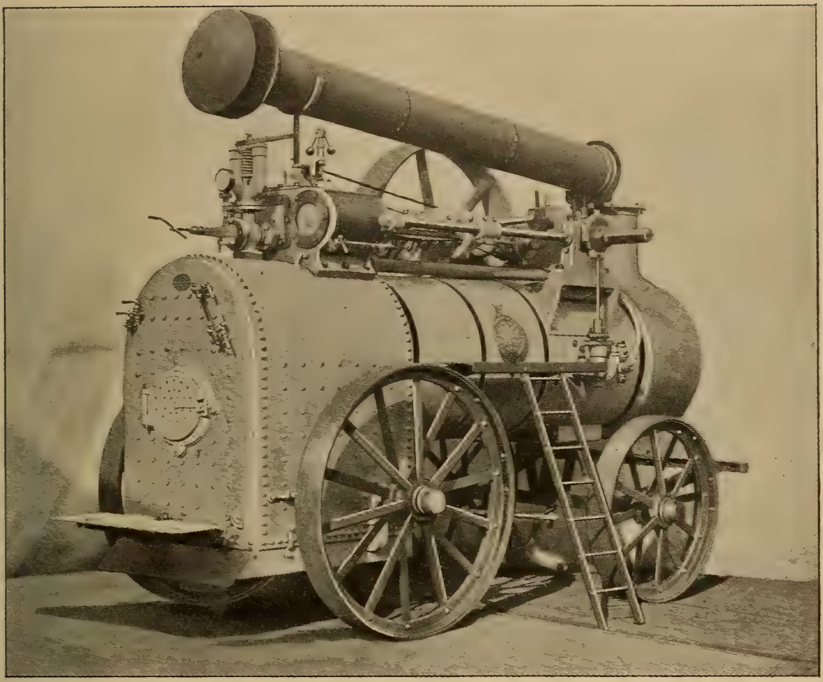


FIG. 23.—A MODERN DOUBLE-CYLINDER PORTABLE ENGINE, BUILT BY MESSRS. ROBEY & CO., LINCOLN, ENGLAND.

worth, of Lincoln, was first exhibited at the Gloucester meeting in 1853. As will be seen from Fig. 11, the cylinder is enclosed within an upward extension of the smokebox. The cylinder was also steam-jacketed, and these improvements were credited with the reduction of the coal to 4.32 lbs. per hour, the lowest yet recorded. This was, no doubt, very largely also due to the excellent proportions of the boiler. This inside cylinder arrangement was considered, and, doubtless, rightly, a most important improvement, though discarded many years since.

No further trials were held by the Royal Agricultural Society until the year 1858, when, at their Chester meeting, preparations were made for a more elaborate series of trials than had been before attempted, and under much more stringent conditions, especially in the matter of simplicity of construction and facility in taking to pieces. For instance, the feed pumps were not to have more than two valves, both to be perfectly accessible. How the accessibility of the second valve would be promoted by the absence of a boiler check valve must be left to the imagination of the reader.

In spite of these regulations, but probably on account of more accurate testing, the coal consumption at these

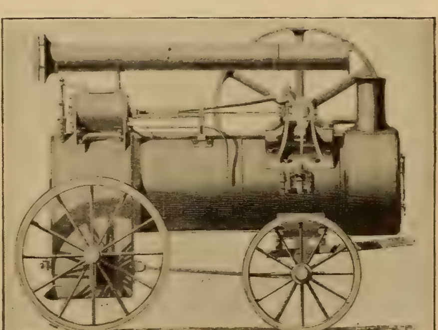


FIG. 24.—ROBEY'S ENGINE WITH SHAFT GOVERNOUR, 1869.

FIG. 25.—ENGINE BUILT BY MESSRS. CLAYTON & SHUTTLEWORTH, LINCOLN, ENGLAND.

trials does not show such a good average result as was achieved by the same makers three years before. The practice of preparing special engines, or "racers," for trials, was also strongly condemned in the report of the judges at this meeting.

The type of locomotive, or portable boiler, shown in Fig. 18, was patented in 1861 by Messrs. Robey & Scott. It will be seen that the water space is carried around under the fire bars, and a highly successful boiler, both mechanically and commercially, this turned out to be. Its only disadvantages were additional weight and increased first cost, but these were more than counterbalanced by its increased steaming power, and the exceptional facilities afforded for the deposit of sludge and dirt in the bottom space, whence they could be easily removed. It is worthy of remark that the same thing was quite recently reinvented by Mr. F. W. Webb, of Crewe, and applied to the boilers of his compound locomotives. Messrs. Robey, it may be remarked, never entered their engines for trial at the Royal Agricultural Society's meetings.

Further trials were carried out by the Society at their Worcester show in 1863, the best result being credited to Messrs. Tuxford for their 8-horse-power engine, fitted with an expansion-valve, and consuming 3.59 lbs. of coal per horse-power per hour. The next great trials were those at Cardiff, in 1872, where the honours were divided between Messrs. Clayton & Shuttleworth

and the Reading Ironworks Co. for engines reported to consume 2.71 and 2.79 lbs. respectively.

In 1869 an engine was exhibited at the Smithfield Club Cattle Show, fitted with the crankshaft governour shown in Figs. 19 and 20, acting directly, by what is known as the wedge-motion, upon the slide-valve eccentric, thus forming an automatic expansion-gear. This arrangement was patented in the same year by Robert Robey and John Richardson. After a careful search, we are unable to discover any trace of automatic expansion-gear being actually applied to the portable engine prior to this, its application having been confined to stationary engines of large power.

The history of the portable engine may be considered as ending at the Cardiff trials of 1872, inasmuch as all further improvements up to date are matters of detail merely. No new type of engine, so far as we know, has been introduced, and the attention of manufacturers has been mainly directed to strengthening, improving and generally, under the wholesome stress of competition, seeing who could produce the best possible article for the money. It affords an example of what biologists call "reversion to type" to remark how such variations, as for example, Tuxford's steeple-engine ; the inside cylinders of Clayton and of Hornsby ; and Robey's closed-bottom firebox, have all disappeared, leaving, now, little to distinguish the engines of one maker from those of another.

Briefly reviewing the improvements in matters of detail during the last fifteen or twenty years, we should be inclined to put in the first place, the improved system upon which the boiler is constructed. A good many years ago, it was tolerably easy to turn out a fairly good engine, but the art and practice

FIG. 26.—ENGINE BUILT BY MESSRS. RUSHTON, PROCTOR & CO., LINCOLN, ENGLAND.

of boiler-making had not then developed itself. Those of us who are of middle age have seen a marvellous change in

FIG. 27.—FRICTION DIAGRAMS FROM ENGINE WITH ORDINARY THROTTLING GOVERNOUR.

FIG. 28.—FRICTION DIAGRAMS FROM ENGINE WITH AUTOMATIC EXPANSION GEAR.

this respect, due, very largely, to the immense improvement in the material worked upon, and the possibility of procuring steel plates of reliable quality at a price which has practically driven iron out of the field.

With this beautifully ductile, almost amiable, material to work upon; with the flanging-press; with the cleverest drilling-machines, with all manner of self-acting tools for planing, turning and boring all plates; with the system of annealing the plates after being worked in the fire; and, finally, with the hydraulic riveter, the building of a boiler may now be considered the assembling together of a number of accurately-fitting parts, rather than a system of forcible combination of pieces of plate by the aid of various persuasive instruments known as drifts and cramps. It is, however, only fair to say that for years before the practice of punching the rivet-holes in boiler-plates was abolished in favour of drilled holes, the workmen had become rather expert at it, and a set of boiler plates, punched

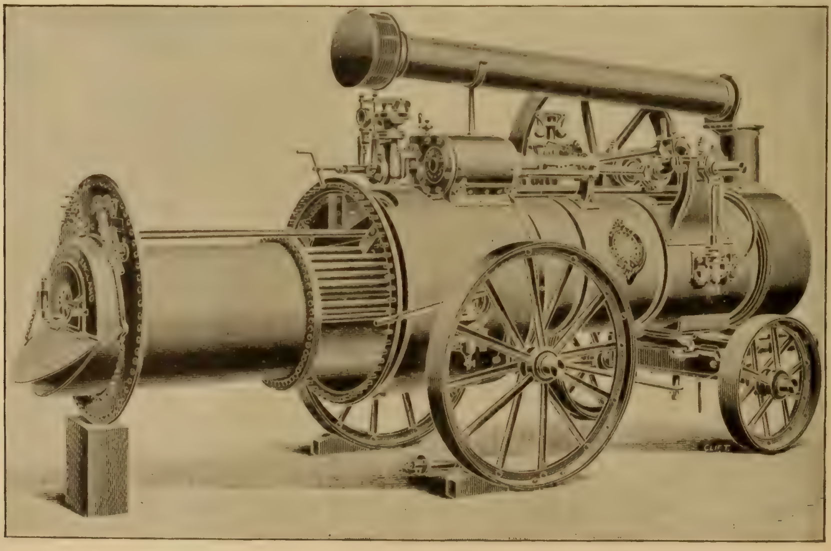


FIG. 29.—A PORTABLE ENGINE WITH REMOVABLE FIREBOX AND TUBES, BUILT BY MESSRS. ROBEY & CO., LTD., LINCOLN, ENGLAND.

from templates while straight, and afterwards bent into shape, would "come together" with a marvellous degree of accuracy, all things considered. But in the best portable-engine practice, iron boiler-plates and punched holes are things of the past, and however good the engine may be, there is the knowledge that it is mounted upon a boiler just as accurately and as carefully constructed as itself.

Another valuable, though less obvious, improvement of recent years has been the greater regard paid to the accessibility of the engine parts. It is no longer considered a desirable thing to pack away every thing possible inside the boiler or inside the cylinder. The very early makers, in common with the latest present-day practice, had the virtue of putting everything where it could be seen and got at. But, between these two eras came a period of neatness and snugness. The exhaust-pipe passed through the steam-space of the boiler; the stop-valve, throttle-valve, and safety-valve, were within or upon the cylinder, and a general effect of sleekness and smoothness was evident.

FIG 30.—ENGINE BUILT BY MESSRS. MARSHALL, SONS & CO., GAINSBOROUGH, ENGLAND.

Inside exhaust pipes absorb and convey away up the chimneys a considerable amount of heat; are difficult to get at, and worse to get out for purposes of repair; and there is always

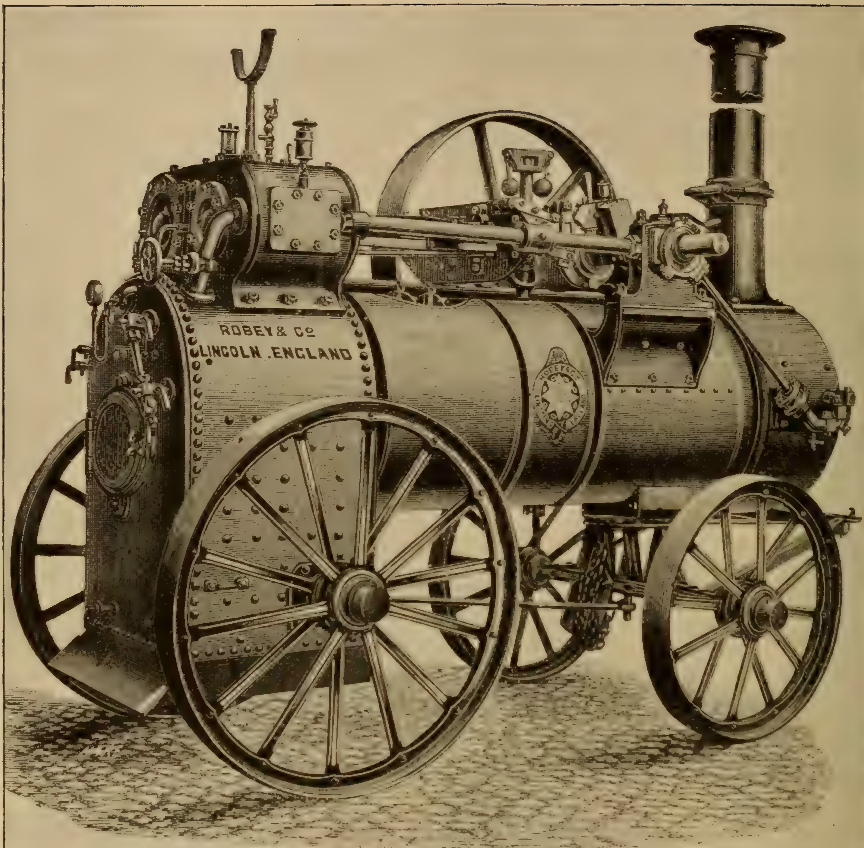


FIG. 31.—A MODERN ROBEY COMPOUND ENGINE.

the possibility of unseen and unsuspected leakage of live steam into the exhaust, owing to decay of the pipe or a broken joint. The steam inlet was also underneath the cylinder, affording another possibility of leakage in an inaccessible place.

At that time the cylinder-casting of a portable engine was a trophy of the art of the moulder. The separate liner, or working-barrel, now universally used, was, at that time, unthought of, and the double walls, forming the steam jacket, with its inlet passages ; the steam and exhaust ports, and their inlet and outlet pipes ; the throttle and stop-valve seats, the safety-valve seats, and various other details were all cast in one piece with the cylinder and steam chest. In a double-cylinder engine all this complication was doubled, still in a single casting ; and the number of cores in a cylinder of this kind made it a matter for wonder that a successful casting could ever be hoped for.

See how these are remedied in a more modern engine, as shown in Fig. 23, for example, and, referring back to Fig. 3, notice that Cambridge's engine of 1843 is fully up to date in this respect. The stop valve is outside the cylinder, and the exhaust pipe runs along the boiler, just as in the more recent engine,—outside. It can, if necessary, be removed in a few minutes, and, when worn-out, does not allow live steam to pass into it and escape, unsuspected, up the chimney. In this engine, Fig. 23,

you will also observe that the plummer-blocks, or main crankshaft bearings, are connected to the cylinders by stay-rods, the former being allowed to slide upon their brackets to allow for the expansion of the boiler while getting up steam.

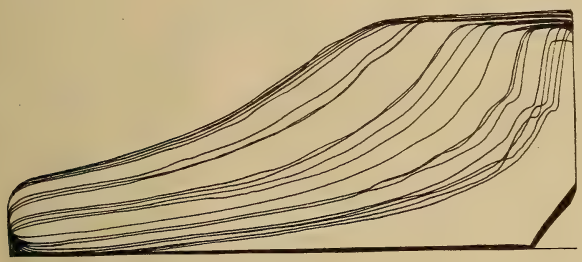


FIG. 32.—EFFECT OF SUCCESSIVE INCREMENTS OF LOAD, WITH AUTOMATIC EXPANSION GEAR.

The much-discussed subject of stay rods claims a moment's attention. It is evident, at first sight, that the conditions differ very much in a portable engine from any other in which the engine is not erected on a boiler liable to continual alteration in length by expansion and contraction. That the stay rod is a very desirable addition in engines, say of 10 horse-power and upwards, in these days of high speed and high pressure, admits of no doubt. But in the case of smaller engines, the comparative strength of the boiler, considered as a girder or base plate, is so much greater, that practice shows there is little need of a stay rod.

But far worse than no stay rod at all is the practice, strangely adopted by some makers who ought to know better, of connecting the cylinder to fixed or non-sliding plummer-blocks, presumably with the view of preventing the expansion of the boiler by main force, the result being that an enormous strain, to which the ordinary pull-and-thrust of the engine is a mere nothing by comparison, is put upon the boiler and all the fixed parts of the engine. In fact, it affords a modern instance of a question much discussed by ancient philosophers, viz., what would be the effect of an irresistible force acting upon an immovable body? At the present day the effect is generally to cause leakage of the boiler, and to develop cracks in the cylinders where the stay rods are attached.

Another improvement of recent years is the now pretty general adoption of automatic expansion gear. It is a curious fact that, although, as we have shown, that there was a thoroughly practicable automatic expansion gear introduced as far back as 1869, it is only quite lately that the public,—the engine purchasing public,—seem to have appreciated its very obvious advantages, and this has had the effect of putting up the working pressure of steam from 45, 50 and 60 lbs., to 80, 90 and 100 lbs.

In Figs. 27 and 28 we have two friction diagrams, the first taken from an engine controlled by an ordinary equilibrium valve governour, and the other a similar diagram from an engine fitted with a link expansion gear, acted upon by a powerful spring governour. These two diagrams are placed together for purposes of comparison. The cut-off point in Fig. 27 is fixed at about

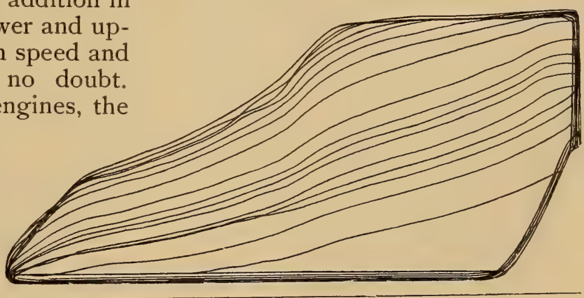


FIG. 33.—EFFECTS OF SUCCESSIVE INCREMENTS OF LOAD, WITH THE ORDINARY THROTTLING GOVERNOUR.

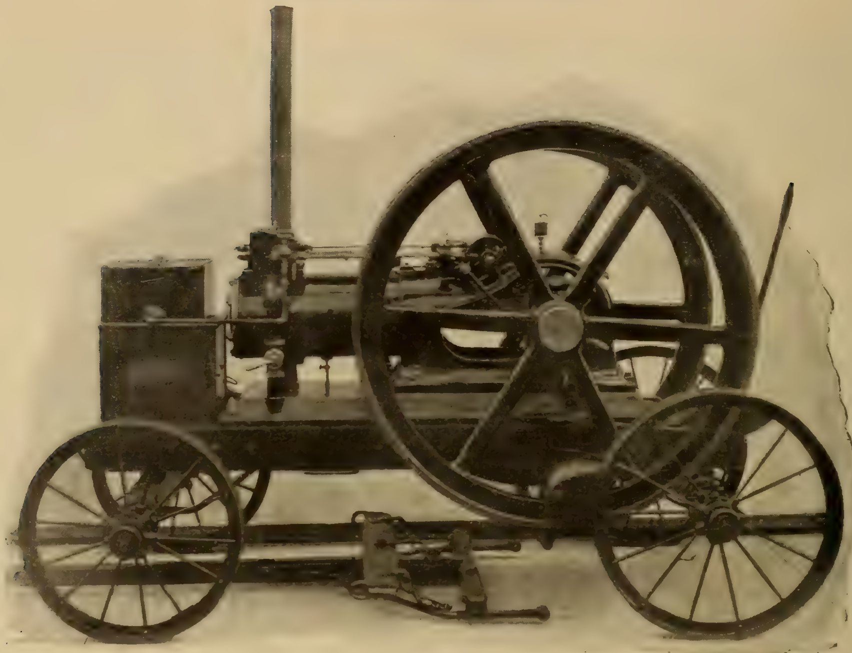


FIG. 34.—A PORTABLE GAS ENGINE, BUILT BY THE DAYTON GAS ENGINE CO., DAYTON, O., U. S. A.

half stroke ; that of the other is automatically varied by the action of the governour. The engines from which they were taken are otherwise identical. It does not need a second glance to discover the benefit derivable from the admission of a small quantity of steam at boiler pressure, rather than a much larger quantity of steam, drawn down to a low pressure by the throttling governour.

Figs. 32 and 33 are reproductions of indicator cards taken from the ordinary and the automatic expansion engines, respectively, under precisely similar conditions. During the time that the pencil of the indicator was in contact with the card, the load upon the brake was gradually increased from nothing (the friction diagram) up to the full test load, the speeds being in each case, and all the time, 135 revolutions per minute. The engine from which the former diagram was obtained is shown in Fig. 31, and may be taken as representing present-day practice. It is unnecessary to enter into details concerning it.

In Fig. 29 we have a precisely similar engine, but with a special type of boiler, adopted for places where the water is too bad for use in the ordinary locomotive boiler. In this case the whole of the heating surface, consisting of the firebox and tubes, with the front tube plates, can be withdrawn for examination and cleaning, by simply unscrewing a few dozen nuts at each end of the boiler. This variation is preferred in some districts on the European continent, and the boiler externally bears a strong resemblance to Cambridge's engine of 1843, as shown in Fig. 3.

Within the last eight or ten years the ever increasing strain of competition has resulted in the production, by one firm after another, of the compound portable engine, and this may almost be said to have exhausted the possibilities in the way of economising fuel in the portable engine. These are now built regularly by most of the leading manufacturers, and are, almost without exception, correctly designed, well worked out and highly finished specimens of up-to-date engineering.

So far as we are aware no triple expansion portable engine has yet been built, though the principle has been applied to some extent, to a kindred class of engine, the "under type," or semi-portable. What the future has in store for the portable engine remains to be seen. Whether or not steam will be superseded as a motive force, the motor on wheels will, it can hardly be doubted, always remain, in some form or other, until the demand for power shall cease for ever.

ELECTRIC POWER IN COLLIERIES.*

By Llewelyn B. Atkinson, A. M. I. C. E.

THE present position of the coal mining industry in the United Kingdom is one deserving of the most thoughtful consideration by all who are interested in the future commerce of the country, and the object of the present paper is to point out how some of the difficulties under which this industry at present labours may possibly be met. The difficulty to be contended with at present may be briefly stated. The possible output, indeed the output at which a reasonable profit can be earned, is greater than the demand at present prices ; and even this demand is threatened by the decreasing price of foreign coal. From whatever point of view it is looked at, the question resolves itself into stimulating demand, and this can be effectually done only by lowering the selling price, which is impossible at present without extinguishing the profit.

To decrease the cost at the collieries, there are, broadly, three courses :—

1. To decrease the payment per ton to the mineral owner.

2. To decrease the wages cost per ton raised.

3. To decrease the fuel expenditure per ton raised.

The first of these is a matter outside the scope of this paper; the second will be briefly touched upon, and the third will be dealt with in some detail.

In the course of the last eight or nine years the author has been in close contact with mining operations in various parts of England and Wales, and the opinion has gradually been forced upon him that there is a very large margin of economy in wages and fuel to be effected. This arises from the fact that economies in labour and fuel which are studied and insisted on in engineering and manufacturing industries are hardly considered in coal mining, at all events in the majority of instances. This broad fact must appeal to every mind that, whereas in almost every manufacturing process or industrial operation the product per man has nearly doubled and the consumption of fuel been halved within the last 15 years, in coal mining the product per man has been practically stationary, and the cost of fuel per ton raised probably nearly so. This is frequently attributed to the stringency of mining legislation, but legislation has largely affected other industries also, and the result cannot be altogether attributed to this cause.

It would be a long task to enumerate the causes which, in the author's opin-

* From a paper read before the South Wales Institute of Engineers.

ion, contribute to this result; but, broadly, it appears to him that what is required, is to do in mining what has been done in every other department of industry, *i. e.*, to lower the cost of wages and material per ton by increasing the product per man and per pound of fuel by the following means :—

1. Improved organisation, both in the working, and more especially in the original laying out of the scheme of working a colliery.

2. More superintendence and supervision underground by thoroughly well informed mining and mechanical engineers.

3. The greater use of mechanical power instead of human and horse labour, and a more economical production of that power.

In short, substitute brains and mechanical power for human labour. It has been already stated that the immediate object of this paper is to deal with the question of the economical production of power; but a few remarks on the subject of mechanical power in collieries may be useful.

The getting of coal resolves itself into cutting and filling and hauling to the pit bottom. In the great majority of collieries both cutting and filling are done without using any mechanical power whatever, and the progress made in introducing mechanical coal-cutters is slow, at all events in this country. A considerable experience, extending over some years with coal-cutting machines in various collieries and various parts of the country, justifies the author in saying that there are hardly any seams under 3 feet 6 inches in thickness that could not be more cheaply worked by mechanical coal-cutters than by hand labour, and with a better product of round coal; but that in probably not 5 per cent. of the collieries of the country is the existing organisation of the filling and haulage sufficiently good to enable machines to be worked with that regularity which will make them pay.

This is the secret of the otherwise unexplained fact that some few collieries have been and are worked by machinery with marked success, whilst the reverse holds good of the majority of cases in which it has been tried. Organisation and superintendence, those are the only secrets of success in cutting coal by machinery; till they are forthcoming, mechanical assistance in this direction must be postponed. In thin seams much might no doubt be done to apply mechanical power to reduce labour and breakage in filling the coal, but the same remark applies to coal cutting.

The use of machinery in the coal face would so much reduce the length of face under work for a given output, that the roads on to the face, being less in total length, could, without increased cost, be kept in a condition enabling mechanical haulage to be used right up to the face, doing away with horses and ponies altogether. These are some of the directions in which mechanical power may be looked for to profitably enable the output per man to be increased. But before this can be done, much will have to be done to improve the general organisation both above and below ground. And this may well be commenced by the economical laying out and conduct of the arrangements for the generation of power above ground.

Consider the conditions under which this is at present carried out! Generally speaking, when sinking operations are completed, a winding engine is put down. Subsequently, as the workings extend, haulage is considered, and some plant, either steam, compressed air, or electrical is provided for this. Later, perhaps pumping becomes necessary, and again a plant (perhaps on another system) is put in. There are various engines at the surface for the screening, repairing shop, and other purposes. All these are of uneconomical types; so there ensues, at every point, waste of heat, and waste of steam, particularly when, as in some cases, separate boilers are put down for each plant. And the answer to any criticism generally takes the form: "Oh, fuel is so cheap at a colliery, that it does not matter." Why is the fuel so cheap;

that is, of such low value? Because it is so small—smashed in hewing, smashed in filling, smashed on the screens, due to imperfect methods and appliances at every point. But, at any rate, it is worth at least 2s. 6d. per ton, and it is generally estimated that from 5 per cent. up to even 10 per cent. of the total output by weight of the collieries is consumed at the surface, and this means, even taking the lower figure, about 9½ million tons, worth about £1,190,000 per annum.

It has been stated by Mr. Foster Brown, in a paper read in 1891 before the British Association, that the probable consumption of coal in colliery engines, taking an average, would be not less than 6 lbs. per H. P. hour. Taking this to refer to indicated horse-power, it is possible to produce the same power with 1½ lb. of coal, or even less; hence it may be fairly said that there is a possible saving to be effected of 75 per cent., worth annually nearly £900,000. It would probably be well within the mark to say that the saving to be effected in labour of handling, and in the maintenance of boilers and appliances for consuming this, would be worth, in addition, say, 65 per cent. of the above sum, showing a possible economy of, say, 1½ millions sterling per annum, a sum equal to over 2 per cent. on the total value of the coal raised, or about 3¾ per cent. of the whole wages annually paid in the mining industries; and if the coal were raised unbroken, so that its value were equal to the average value of the coal sold, these figures would rise to 3 per cent. of the value of the total coal raised, or 6 per cent. of the wages paid.

It may be stated at once, that to realise these economies, the power required must be produced by compound or triple-expansion condensing engines, appliances almost unknown in colliery work, and to do this there is no doubt that the whole power required at the colliery must be produced in one, or at most, two engines, and distributed with as little loss as possible to the points where power is required. There are various methods of distributing power, but some of them are applicable only to particular cases, or in particular circumstances; the only two of general applicability are compressed air and electricity.

Of these, whilst under favourable circumstances, compressed air can be made to give a favourable efficiency, its application in mining is discounted by two important considerations of economy. To utilise compressed air with efficiency—(1), the pipes must be free from leakage; (2), the air must be heated before being used. These two conditions are practically unrealisable, and hence the efficiency of air transmission in colleries is and must necessarily be low. The cost of plant and extended air mains is also high.

The advantage, therefore, in point of view of first cost and efficiency as a means of distributing power rests with electricity; the economy of the cables compared with air mains, and the facility for extension and alterations to the position of the machinery, make electricity an ideal means of distributing power.

There is, however, a question to which I must refer, viz., that of safety. This question of safety is one which has from the first introduction of electricity in mining been prominently before engineers, though it may be noted that among those who have had practical experience of its use in mines the objection is rarely raised. In a paper read in 1891 before the Institution of Civil Engineers by the author, in conjunction with Mr. C. W. Atkinson, this question was somewhat fully dealt with, and certain conclusions were arrived at which time and experience have gone to confirm; but, as this question is to some minds still an open one, and as additional experience has added to the knowledge of the subject, it may be well to deal with it again at some length.

There are two distinct questions:—

1. The safety of an electric motor, which may spark at the commutator.

2. The safety of a system of cables which may be ruptured whilst carrying an electric current.

Dealing with the first of these, it has been shown from theoretical considerations and by practical tests that the amount of sparking which exists with electric motors of good construction is unable to ignite firedamp, owing to the fact that the temperature is never sufficiently high, and it is only, therefore, in exceptionally abnormal circumstances, such as a brush falling out of its holder or becoming displaced absolutely on the commutator, that the inflammation of firedamp can be effected; and it has also been shown conclusively by experiment that there are in the market methods of enclosing either the whole machine or the armature and commutator, or the commutator alone, which, even under these abnormal circumstances, entirely prevent either the access of firedamp or the ignition of firedamp outside the machine.

Practical experience is in accord with experiment and with the principles named, and the author knows of no recorded instance where there has been an accident from the use of an electric motor in a coal mine. In connection with this, reference may be made to the question of "commutatorless" motors worked by multiphase alternating currents. Although such a motor may have no commutator, if it has to be regulated as to speed; or, to start with a load on, it must have brushes and collecting rings, in which case the displacement of the brushes under abnormal circumstances may have, in a modified proportion, the same result as in an ordinary motor. Another circumstance in connection with such motors, as at present constructed, is that the maximum turning moment they will give has a limiting value, beyond which it decreases as the load increases, even though the current increases, and that at any other than the normal speed the efficiency rapidly falls.

A further point is that the losses in the cables and the dynamos, which with continuous currents are proportional to the power transmitted, are not proportional in the case of alternate currents, whilst in addition, as 250 volts alternating will give the same "shock" as 500 volts continuous, which is generally treated as the maximum advisable in a colliery, the cables have to be of about twice the area of section for the same power; hence these various considerations contribute to this, that the advantage of such motors at full load and full speed are to be balanced against their disadvantages at less than full load and at other speeds, and in the particular case of colliery transmission these points are large factors.

Let us return now to the second point in the question of safety, viz., the possible breakage of a cable. This may be at once overcome if the cables are buried below the surface, but as this method has the disadvantage of expense, and frequently of deterioration of the cable, we may consider the case of a cable hung from the walls or timbers.

In this case if the cable does break, the ends are quickly parted; the spark may continue for the fraction of a second, but it has been shown by the experiments of Messrs. Wüllner and Lehman at Aix-la-Chapelle, which experiments were accepted as conclusive by the Prussian Firedamp Commission, "that even violent sparks from rupture of the current, accompanied with the explosion of fragments of iron in a state of combustion, had no effect on the inflammation of firedamp."

Considerable light has, in the author's opinion, been thrown on this question by the facts recently stated by Prof. Vivian B. Lewis. It appears that the ignition of firedamp arises in most cases, not from the raising of the temperature to the ignition point of firedamp, which is very high, but by the raising of it to the point of its decomposition with evolution of hydrogen, which, becoming ignited, eventually ignites the firedamp. This requires two things:—(1) Time (and Prof. V. Lewis states that 10 seconds is in some cases necessary); (2) the maintaining of a particular mass of gas in contact with the point where the heat is developed, long enough to effect the operation quoted. Neither at the commutator of a motor, nor at the point of rupture of a cable,

are these conditions fulfilled. In the face of the facts and experiments and experience now at disposal, those who raise the objection to electricity in mining on the ground of safety ought, in the author's opinion, to bring some proofs of that danger if it is to receive consideration. Notwithstanding the extended use of electricity, these causes of accidents do not occur, and, in the opinion of many well qualified to give it, the danger arising from electricity is less than that arising from safety lamps, and enormously less than that arising from almost any explosive agent now in daily use.

Having dealt with this question, it remains to be asked,—Is the present position of power distribution by electricity such that we may use it with confidence for the whole of the power required at a colliery? The author's answer to this is, yes. In support of this may be given the following facts :—

The largest engine at a colliery is the winding engine, and suppose this to require to be capable of developing power at full speed of 1000 H. P., which is an outside figure. This could be well replaced by two motors of 500 H. P., one on each end of the shaft of the drum, without gearing. There are numerous cases of dynamos and motors of this power working with ease and satisfaction and giving no difficulty whatever, and operated by ordinary mechanics with no more trouble than an ordinary steam engine. Motors of smaller sizes are in use all over the world, with universal satisfaction as to ease of manipulation and low cost of maintenance.

Are the claims made for efficiency of electric distribution of power realised? On this point the author has examined, carefully, tests made by himself and by others on electric power plants, and has arrived at this conclusion—whilst the efficiency of distributing electric power and its utilisation in the motors does come up to that claimed, the efficiency of the production of electricity is not, as a rule, as high as is claimed, or as high as may be realised, and the reason is that sufficient account is not taken of the fact that the average load is considerably less than the maximum requirement. In one known case, where the efficiency of electric generation, that is, the proportion between the electric power delivered to the cables and the indicated horse-power of the engine, is as high as 86 per cent. at full load, it falls to 74 per cent. at half-load, and to about 58 per cent. at one-quarter load. The reason for this is to be found in the power the engine takes to drive itself. The engine is generally arranged to work with an economical cut-off at the full load or maximum power, and consequently is larger than necessary for all smaller loads. It should be arranged to work with an economical cut-off at the average power. The moral is to use engines with automatic expansion valves, permitting the engine to work with a cut-off as late as half or five-eighths of the total cylinder volume when developing the maximum power, and working with a more economical grade of expansion at the average load.

To apply the principles advocated in this paper, the method to be adopted should be as follows :—When a colliery is opened, an estimate must be made of the power which will ultimately be required for the whole colliery. It need not be all provided for at once, but the arrangements must be such that what is provided will be worked at an economical load, and that by simple duplication it may be increased.

An example is given below which may be considered to represent an average case, where there is no very heavy pumping.

TABLE OF POWER REQUIRED AT A COLLIERY.

	Maximum Power H. P.	Average Power H. P.	Minimum Power H. P.
Winding	700	225	0
Fan engine	60	60	60
Pumps	50	50	50
Haulage	200	100	0
Lighting	20	10	10
Screens	20	20	20
Shops at surface	20	5	5
Capstans for wagon handling	20	10	10
Total	1,090	480	155

The power required by the winding and haulage engines is what would

probably be required in a colliery drawing about 1500 tons per day, and the maximum power required by the winding engine is reckoned on the assumption that the weight of the ropes is unbalanced, and the average on the assumption that the winding takes 40 seconds and the unloading and loading 25 seconds. Variations will correspondingly affect these points, and must be made to suit each case.

These powers are those required at the separate machines, and if we take it that the loss in the cables at full load is 5 per cent., which will be ample, as the bulk of the power is not far from the source, and that, at the average load and upwards, the indicated power is $\frac{100}{86}$ of the power delivered to the cables, we get the following as the indicated power required at each load, which, assuming that the electric motor will transform only as much electric power into mechanical power as a steam engine would convert of indicated power into mechanical power, gives a direct comparison between the actual indicated power required if all the engines were worked direct from the boiler, or by the distribution thus to be effected.

INDICATED H. P. OF GENERATING ENGINES.

Maximum.	Average.	Minimum.
1,330	572	265

Now, it will be observed that the average power is 572 I. H. P., as compared with 480 I. H. P. actually required at the engines. But taking for the former Mr. Foster Brown's figure of 6 lbs., and for the latter 1½ lbs., the economy resulting is found from the fraction—

$$\frac{6}{1.5 \times \frac{572}{480}} \text{ or } \frac{6}{1.78} \text{ or } \frac{100}{29.6},$$

not differing far from the possible economy spoken of early in the paper.

That such figures are realisable in practice is shown by the figures given in a paper read before the North of England Institute of Mining Engineers by Mr. Alexander Siemens, and published in Vol. viii., Part 2, of the *Transactions* of the Federated Institution of Mining Engineers.

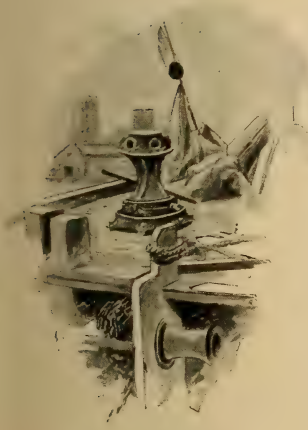
Tests are there recorded where, with a plant considerably smaller than that here considered, a consumption of 2.62 lbs. per E. H. P. hour, equivalent to 2.25 lbs. per I. H. P. hour, were obtained; and in the discussion on the same paper, reference was made by Mr. D. B. Morison to a plant using 2 lbs. coal per E. H. P. hour, equivalent to 1.72 per I. H. P.

The writer is aware that in thus advocating the generation of the whole of the power in one engine, or pair of engines, he is advising a very radical departure from existing and well tried methods; but the advantage in economy is so great that, in his view, a revision of method must take place.

THE DEVELOPMENT OF THE SHIP WINDLASS.

By Edwin H. Whitney, M. E.

"Build me straight, O worthy master!
Staunch and strong, a goodly vessel,
That shall laugh at all disaster,
And with wave and whirlwind wrestle!"



WHEN one reads Longfellow's "Building of the Ship," a peculiarly sympathetic and responsive chord is struck in the heart of the reader, and one feels, in its perusal, that it would have been an honour and a proud event to have taken part in building so staunch and beautiful a creation as is there portrayed.

One of the principal things that the worthy ship-master must have had in his inward thought, in order that she might be "a goodly vessel" in every part, "and with wave and whirlwind wrestle" was, that she should be furnished with a reliable windlass. And no doubt he fashioned one of ponderous timber, iron bound and of great strength.

In its primitive form there is no more homely piece of mechanism than the ship windlass. All that it suggests to the lay mind is strength and ruggedness. Its use in ships is for raising or weighing the anchors, or obtaining a purchase on other occasions. It works on the principle of the wheel and axle, and consists, in one of its simple forms, of a strong, polygon-shaped beam of wood, placed horizontally, and supported at its ends by iron spindles which turn in collars or bushes, inserted in what are termed the windlass bitts. This large axle is pierced with holes, directed toward its centre, in which long levers or handspikes are inserted for turning it around when the anchor is to be weighed, or when any purchase is required. It is furnished with pawls to prevent it from turning backwards when the pressure on the handspikes is intermitted.

In working the windlass, one man, for example, having introduced his bar, about six feet in length in a hole nearly vertical, steps up and, seizing it as high as he can reach, throws himself backward, and as it advances, he presses with greater and greater weight upon it

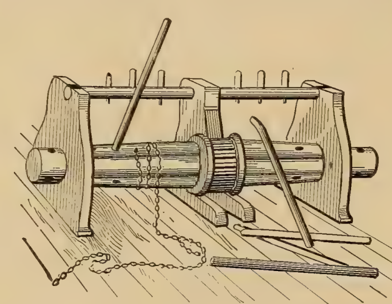


FIG. I. A PRIMITIVE FORM OF WINDLASS.

till he brings it horizontal. This brings some other hole vertical, into which another man inserts his bar, and thus the windlass is made to revolve, winding the rope or chain about its barrel.

The origin of the windlass is so far in the dim past that its first application to vessels is unknown, and yet the principle involved and the art of raising weights was known and practiced in ancient engineering. In the "Viking Age," by Paul B. Du Chaillu, we are

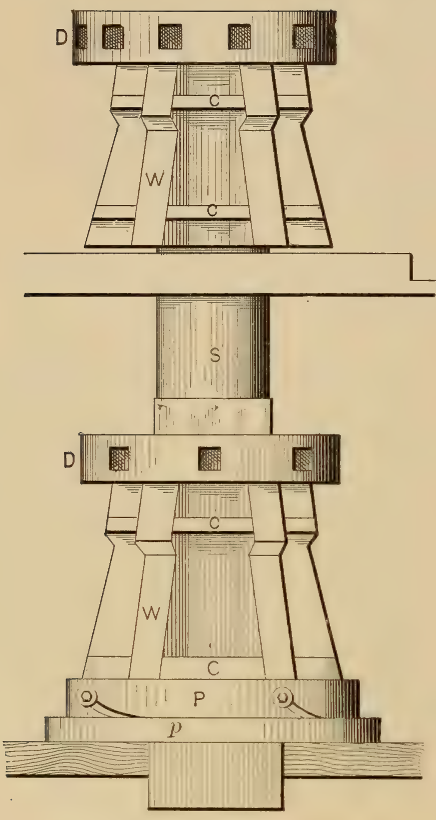


FIG. 2. A CAPSTAN OF 100 YEARS AGO.

told that "when ships were in harbour they were tied with fastenings, communicating with the shore by means ot bridges or gangways. * * * In one mode of naval warfare of the Norsemen, cables were stretched across the mouths of rivers or harbours, in order to prevent ships of the enemy from entering," and that, "Olaf stationed one ship on each side of the sound and had a thick cable stretched between them; and Olaf's men drew the cable under the middle of the keel of the enemy's 'skied' and hauled it with windlasses and thus upset the vessel."

In the olden times smaller vessels employed a windlass, but on board men-of-war a capstan was used for weighing anchor, working upon the same principle as the windlass. It was a strong massive column of timber, formed like a truncated cone, its upper extremity pierced with a number of holes to receive the capstan-bars. A capstan was distinguished from a windlass by being vertical instead of horizontal.

Sir Walter Raleigh informs us that the first use of the capstan on board of English ships took place in his own time, and was one of the many improvements in naval architecture which occurred during the reign of Elizabeth. Sir William Monson, too, who wrote about the same period, mentions the capstan as being then commonly used on board of ships, and after enumerating the several parts, under the same names by which they are now known, observes, that there are two capstans employed in large ships, a main capstan and a jeer, or assistant capstan.

The capstan was probably obtained through the French from the Spaniards or Portuguese, who, from the use of the word "cabestante" in the second voyage of Columbus, appear to have been acquainted with it at least as early as the latter part of the 15th century. In the first rude form of the capstan, the barrel was plain and cylindrical, and the bars passed entirely through the head. It

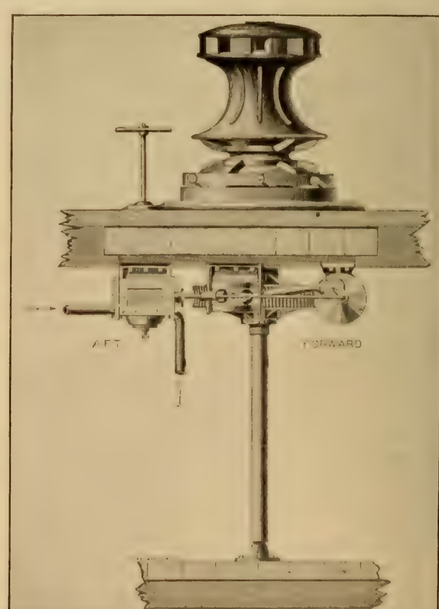


FIG. 3. STEAM ATTACHMENT MADE FOR U. S. NAVY CAPSTANS.

was unprovided with stops or pawls to take the recoil, and great difficulty was experienced in surging the rope, or, as it is termed on shipboard, "the messenger."

Some of the earliest improvements that took place in the capstan, were the result of prize questions, proposed by the French Academy of Sciences in 1739 and '41. One of the improvements was a method of "surging the messenger," invented by Deshayes, De Vallons, and Duval. Le Lande had a project of this kind, which was approved by the Academy of Sciences in 1794, and consisted in applying a helix or screw round the barrel of the capstan, by which means the messenger was raised with every coil, and finally delivered at the upper part. Le Lande also appears to have been the original inventor of falling pawls.

The capstan that was in common use in the latter part of the last, and the early part of the present century, was made of two parts, attached, one above the other, to the same vertical axis, one being on the quarter-deck, and the other on the main deck, of a ship. Both parts were turned by men acting against the bars of both at the same time. The plain barrel of the capstan had been improved by additional pieces, securely fixed to it, and called whelps. The capstan head was fastened to them as well as to the barrel, and, being trimmed slightly conical, greatly facilitated the surging of the rope. This form of capstan is represented in Fig. 2. It consists of the spindle *S*; the drumheads, *D*, *D*; and the whelps *W*, *W*, of which *C*, *C*, are the checks; *P* is the pawl-head, and *p*, the pawl-rim.

It may not be amiss here to explain some of the terms used, and orders given, on shipboard, in connection with the capstan. To "rig the capstan," is to prepare it for heaving by fixing the bars in the holes; to "man the capstan," is to place the sailors at it in readiness to heave; to "heave at the capstan," is to cause it to turn by pushing with the breast against the bars; to "come up with the capstan," is to turn it the contrary way, so as to slacken the rope about it; and to "swifter the capstan-bars," means to fasten a small rope round the outer ends of all the capstan bars before heaving round, so that they cannot be accidentally unshipped.

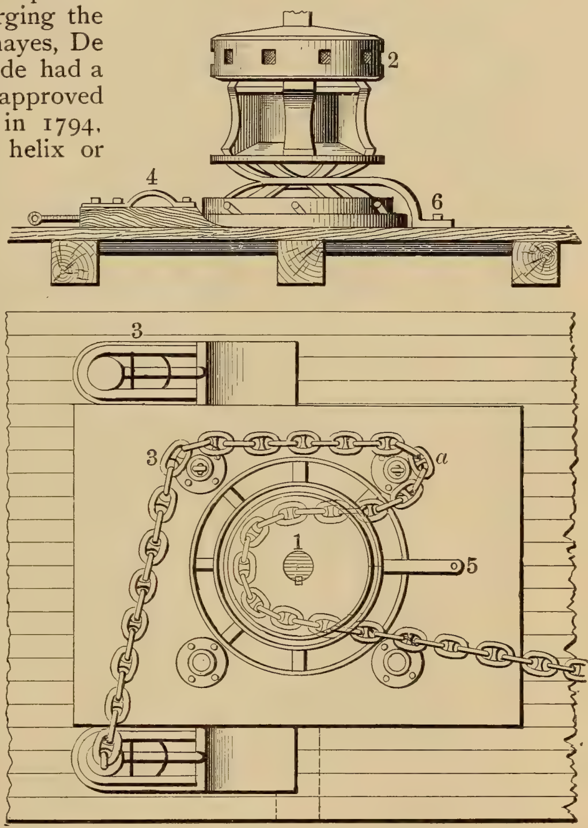


FIG. 4. THOMAS BROWN'S CAPSTAN.

In 1819 Captain Phillips improved the capstan by separating the spindle into two parts and connecting these by a movable clutch. When the clutch was raised, the capstans were separate and became two distinct machines. The lower capstan was fitted with internal gearing in its base, having a ratio of 4:1.

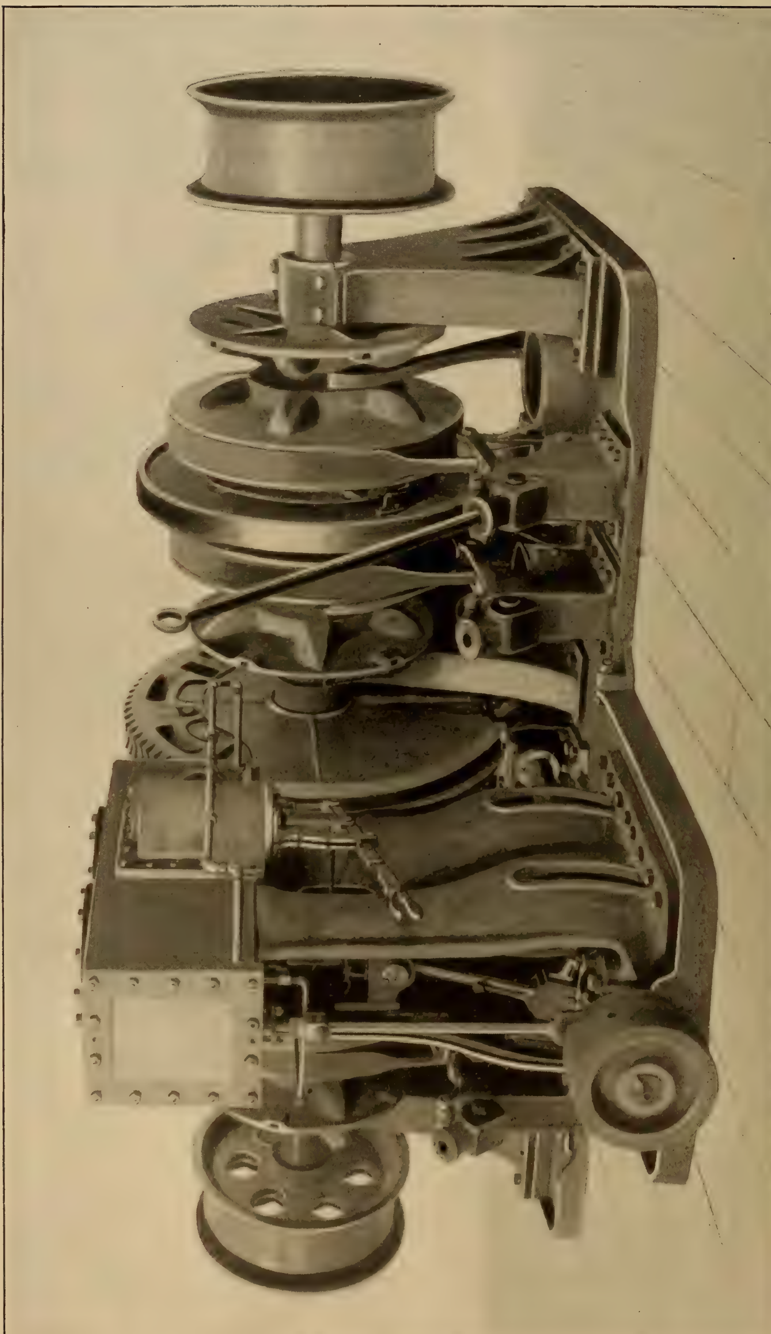


FIG. 5. THE U. S. SS. "INDIANA" AND "MASSACHUSETTS" TYPE OF WINDLASS, BUILT BY THE AMERICAN SHIP WINDLASS CO., PROVIDENCE, R. I., U. S. A.

Mr. Hindmarsh, of Newcastle, England, obtained a patent in February, 1827, for placing the gearing for increasing the power of the capstan, partly in the head and partly in the upper portion of the barrel. James Brown in his capstan, patented in 1833, instead of applying the moving power by handspikes, acted upon two fixed rims of teeth round the top of the capstan, by a worm or pinions turned by a winch. This was the pioneer of the present crank capstan.

In weighing anchor with the capstan, rope messengers were used. They were passed three times round the capstan, and, with an eye at each end, were lashed together. The rope messengers were cut from five to eight fathoms longer than the distance between the capstan and the bow, in order that the men might hold on when the cable was hove in. Nippers, made of rope, from four to five fathoms long, were used to attach the cables to the messenger. These were taken off when the chain was hove, and came aft to the cabin locker, or if the cable was of hemp, to the hatchway near the tier.

The next step in improving the capstan consisted in placing a chain wheel on the bottom of the capstan barrel, and the messenger was made of chain, having a large link and a small one. The spikes of the wheel entered this latter as the wheel was revolved. The messenger was passed half around the capstan, taken forward around the rollers in the bow and the two parts of the messenger were shackled together. Rope messengers were supplied to each ship, in case the chain ones should become defective.

Mr. Thomas Brown, of London, introduced several improvements. The principal one of these, and the method of taking the cable, are illustrated in Fig. 4 The barrel was fitted with a chain wheel that had suitably indented grooves for holding each chain link as the capstan revolved. The numbers 1 and 2 represent the plan and elevation of the capstan, for working various sizes of chain cable; 3 and 4 are the plan and elevation of the deck pipe stopper, to be used for checking the cable when bringing the ship to, and for riding by when at anchor; 5 and 6 are the plan and elevation of the clearing guard.

The Brown capstan, with an iron barrel and head, was manufactured by Wm. H. Jackson, of New York. It was a very popular design and hundreds of vessels in the United States and Europe have been fitted with it. At one time it was in use with slight modifications on nearly all the vessels of the U. S. Navy, and some of the older ships still have it. With the introduction of auxiliary steam engines on ship board, the application of steam to the capstan took place.

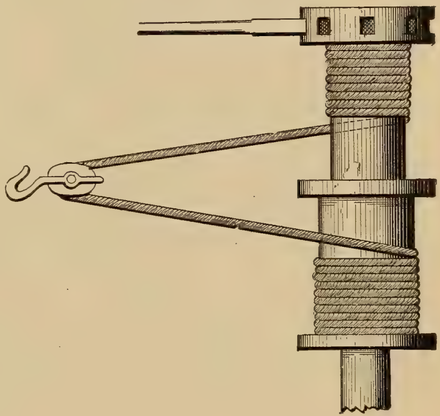


FIG. 6. ECKHARDT'S POWER CAPSTAN.

The firm of Thurston & Gardner, of Providence, R. I., U. S. A., applied steam power to their capstans by means of heavy spur gearing, driven by a pair of 14″ by 14″ engines, with cylinders set at right angles. The U. S. S. S. "Nipsic," "Swatara," and others have the capstan, with engines arranged as in Fig. 3, driving the capstan through worm gearing. The engines were supplied by the Manton Windlass and Steam Steerer Co., of Providence, R. I.

The American Ship Windlass Co. of the same place built engines to be applied to the capstans on board the U. S. S. S. "Adams," "Essex" and other ships. Of the vessels of the revived American navy, the "Boston" and "Atlanta" are fitted with steam capstans, or, as they are now termed,

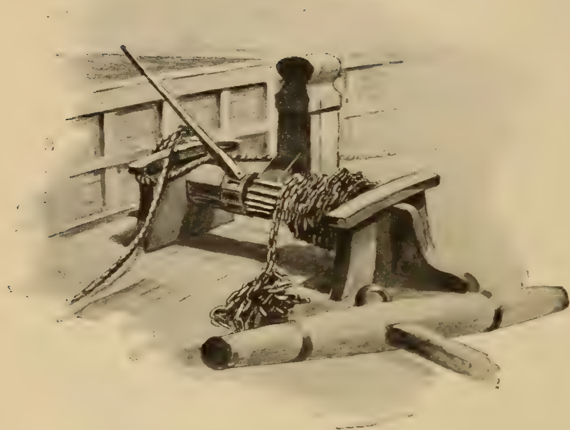


FIG. 7. WINDLASS ON THE COLUMBUS SHIP "NINA."

vertical windlasses, manufactured by the above firm, and they are the only vessels in the new navy that use this type. The U. S. S. S. "Chicago" had at first a double capstan, but it was afterward replaced by a modern windlass.

The capstan has now become obsolete in the United States, and it is used only in rare instances. The old line officers clung to its use as long as possible and were rather conservative about making a change to the horizontal type of windlass. The writer recalls one instance where it required the convincing proof of two hundred names of the best ships in the world, which used the horizontal type, to show its superiority over the vertical type, before the appointed captain of one of the battleships under construction, would consent to its adoption in his vessel.

In the early days of wooden capstans and wooden windlasses, the reason of the adoption of the capstan on vessels of war, was its compactness and its superiority to the windlass in point of quick work, because in the latter the

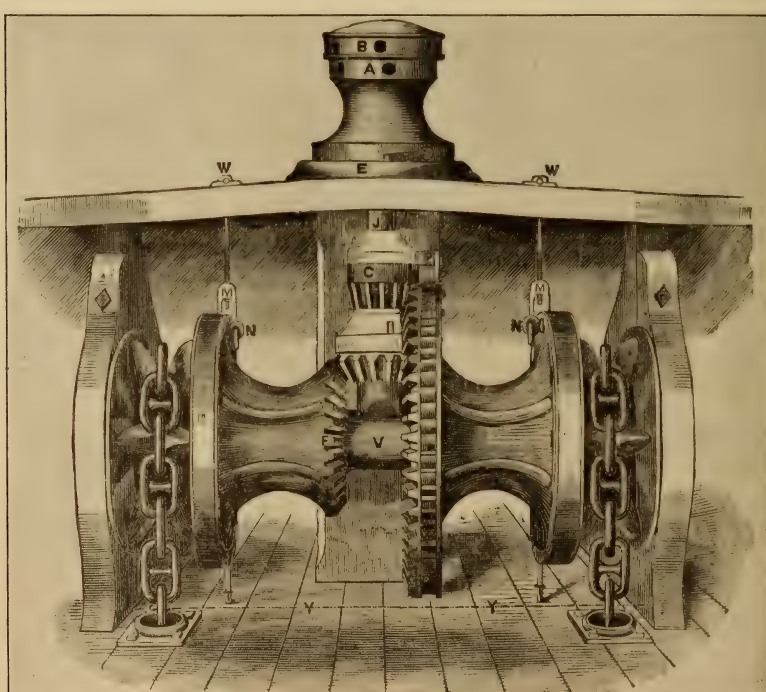


FIG. 8. EMERSON'S WINDLASS.

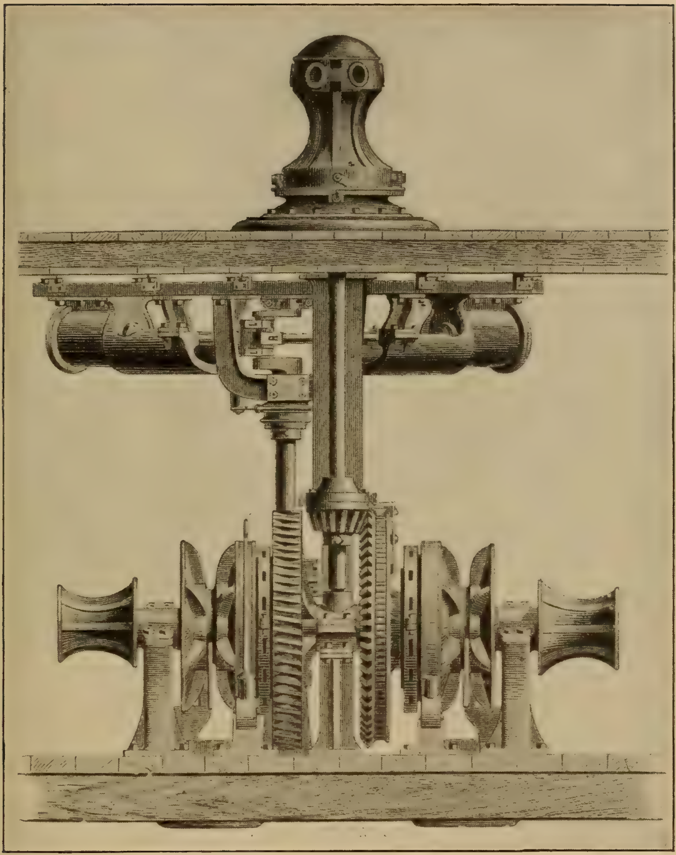


FIG. 9. STEAM CAPSTAN WINDLASS, MADE BY THE AMERICAN SHIP WINDLASS CO.

levers must be shifted in to fresh holes four times in each revolution. A larger number of men also could be employed at the capstan bars than at the handspikes of the windlass, and they could work continuously. But, to offset this advantage, the men could exert their strength more effectively at the windlass than at the capstan, since in the latter case they are employed to push horizontally, when they exert a force of only about 35 lbs., whereas in the windlass they apply their whole weight at the extremity of the lever, and the average weight of a man is about 150 lbs., or four times his power of pushing.

The windlass known as the Chinese or differential windlass, is a species of capstan consisting of an upright shaft, forming two cylinders of different diameters, round the lower one of which a rope is wound. This, after passing through a movable pulley to which the weight is attached, is again brought back to the shaft and wound round the upper or smaller cylinder, in a direction the reverse of that which it had upon the lower one. It is evident that when the shaft is turned the same way as the coil upon the upper cylinder, the quantity of rope taken up will exceed that given off, and, consequently, the pulley and weight attached to it will be drawn to the machine, and the effort which is exerted at the extremity of the capstan bars will be to the weight raised, as half the difference between the diameters of the cylinders is to the distance at which

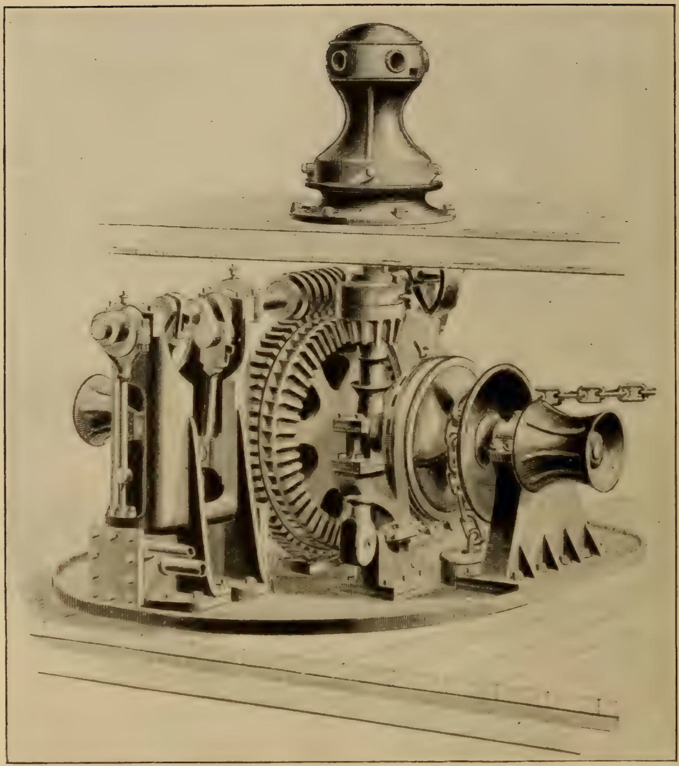


FIG. 10. ANOTHER STEAM CAPSTAN WINDLASS, HERMAN WINTER'S DESIGN, MADE BY THE AMERICAN SHIP WINDLASS CO.

the power acts from the shaft. This differential windlass was reinvented both by G. Eckhardt and R. M'Kean, without either of them being aware that it had been employed in China from an unknown period. The Eckhardt capstan is shown in Fig. 6.

The style of windlass used by Columbus on the caravel "Nina," is illustrated in Fig. 7. This sketch was made on board the restored "Nina" that was on exhibition at the Chicago World's Fair. The primitive form of wooden windlass is in use to-day on board some of the old ships of the merchant service, in many fishing vessels, and in some of the cheap coal schooners. The method of heaving the windlass has been improved by substituting, in place of the handspikes, brake levers that act upon a ratchet lever, fitted with pawls and working upon a ratchet rim, secured about the body of the windlass.

From the year 1790 to 1895 two hundred and five windlass patents have been taken out in the United States. One-half of these have been issued since 1874, and up to that year fifty-five patents had been granted on capstans. The first windlass patent taken out was issued on August 24, 1804, to H. Betts, of Norwalk, Conn., and the first capstan patent is dated October 6, 1810, and was taken out by J. Galvin, of Philadelphia.

The development of the ship windlass has kept pace with improvements in ship construction. In the days of wooden ships wooden windlasses were used; but at the present time of highly-powered, heavily-armoured steel battle ships, the wooden windlass has given place to the cast steel, machine-cut gearing, and steam-driven modern

windlass. The first instances of the application of steam to a windlass in the U. S. Navy were on the "Trenton," and in the merchant service, on the steamer "City of Waco," the "State of Texas" and the "Western Texas" of the Mallory Line. In the latter cases the windlass was an ordinary Emerson windlass with a small blower engine connected through spur and bevel gearing to the large gear of the windlass.

The original Emerson windlass consisted of a horizontal shaft on which were loosely mounted two chain wheels or "wild-cats," as they are termed. They were adapted to be locked by blocks, or plugs, to driving-heads, secured to the shaft, and driven by two sets of bevel-gearing, connected with the spindle of the capstan on the deck above. The peculiarity of this windlass was a combination of the capstan and windlass and the ingenious arrangement of the parts by which a heavy purchase or a quick motion could be given at will, simply by turning the capstan round with the sun in the one case, and in the other, against it. This windlass is shown in Fig. 8

Various methods of driving the windlass by steam were used, one of the first to become a standard being shown in Fig. 9. This type was extensively used for about nine years, from 1874 to 1883, and is still to be found on many vessels. In 1882, when the "Excelsior" of the Morgan Line at New York was built, the superintending engineer, Herman Winter, suggested the type shown in Fig. 10. This was made by the American Ship Windlass Company, and placed on board. The improvement over the previous wind-

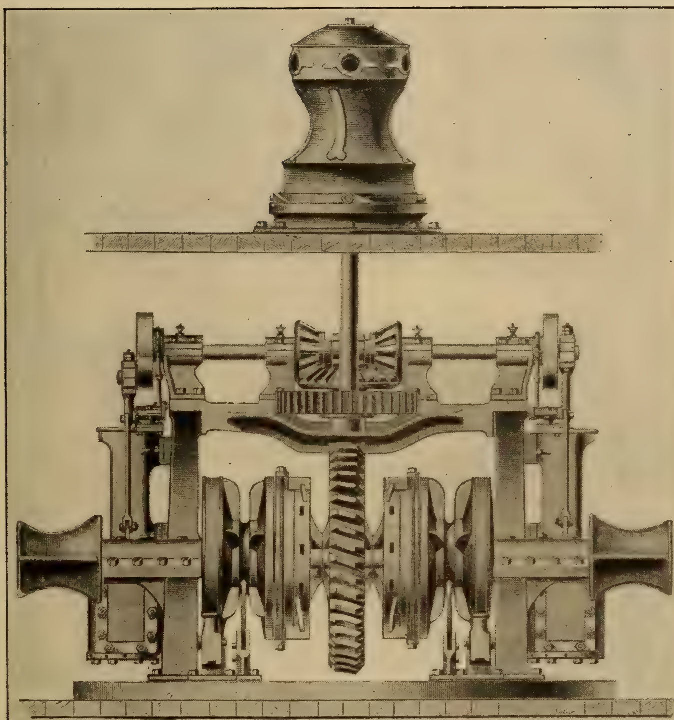


FIG. 11. A STEAM CAPSTAN WINDLASS, BUILT BY THE CHASE ELEVATOR AND MANTON WINDLASS CO., WARREN, R. I., U. S. A.

lass consisted in placing the driving engines and the windlass bitts all on one bed-plate, and this practice has since been generally adopted in all vessels of this class. On many steamers of the "whaleback" fleet the windlass shown in Fig. 11, and built by the Manton Windlass Company, was used.

The standard type of steam capstan windlass, made by the Bath Iron Works, of Bath, Me., U. S. A., is shown in Fig. 12, and also in the smaller cut, Fig. 14. The windlass and engines are complete on one bed-plate. The engine has double cylinders, with piston valves. The cylinders are set at right angles to each other, and make angles of 45 degrees with the bed-plate. The crank shaft carries the worms which drive the windlass and capstan shafts. The windlass may be driven by hand from the deck above through a capstan. To this end, a coarse-pitched, quadruple-threaded worm on the capstan shaft engages with a worm-gear on the windlass shaft. The wild-cats are locked and unlocked by forcing them in and out of connection with positive clutches by a screw cut on the windlass shaft. The type of windlass made by the Globe Iron Works Company of Cleveland, O., and built under their patents of 1889, is shown in Fig. 15. It is in use on the American Lake vessels built by them.

Nearly all the windlass companies mentioned build special windlasses to meet particular cases, and to show an intermediate step in the development of the windlass, from manual to direct steam power, a hand pump brake type of windlass is shown in Fig. 13 that is

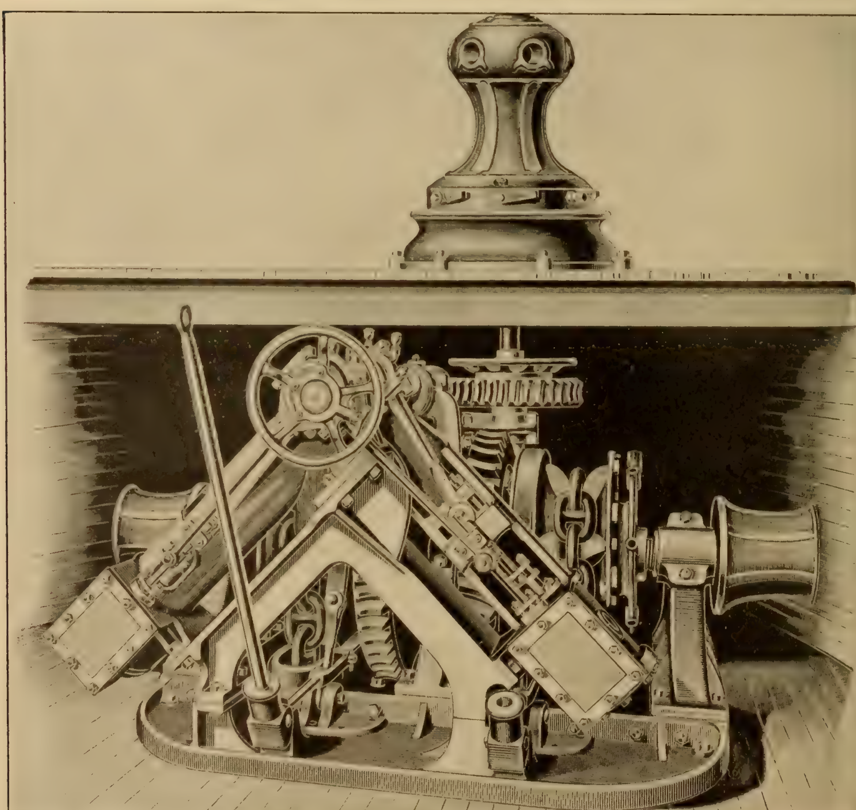


FIG. 12. STEAM CAPSTAN WINDLASS, BUILT BY THE BATH IRON WORKS, BATH, ME., U. S. A.

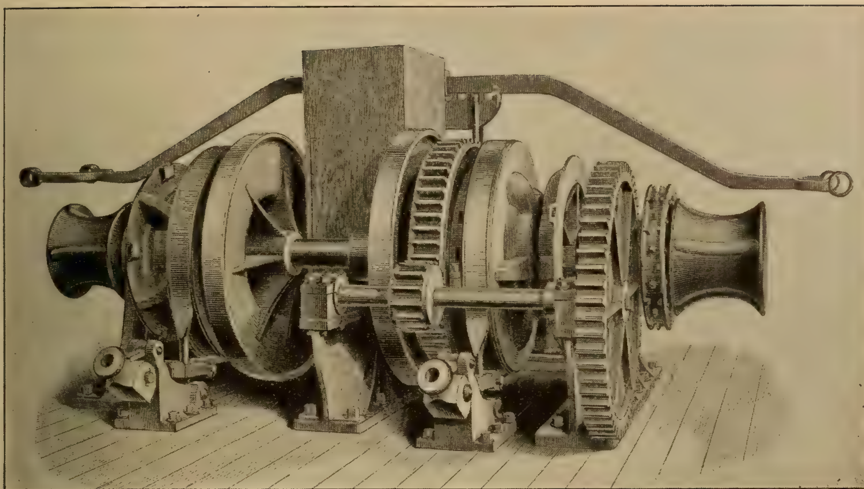


FIG. 13. A PUMP BRAKE MESSENGER CHAIN WINDLASS.

adapted to be driven by a messenger from the donkey-engine on board the vessel. Many coal barges and large schooners employ this method of taking anchor.

As might be inferred, the windlass invented by Fredrick E. Sickles had some ingenious features. It was a steam pump-brake windlass, and had an automatic pressure controlling valve, and an indicator limiting the tension on the chain cable. The driving worm of the worm-gearing was hung on a vibrating shaft for disconnecting it. The slide-valve of each cylinder was so proportioned, in relation to the steam and exhaust ports, and to the eccentric, as to keep the exhaust port open until each engine had passed its centre, for the purpose of letting out water that might have accumulated within the cylinders. The cylinders and steam chests were in such a position that this would take place.

This form of windlass is on board the U. S. monitor "Terror," and as its engines were not reversible, a reversing gear was designed for it by the writer, and made by the American Ship Windlass Company. Among other windlasses used upon the U. S. monitors were some that were brought out at the Hope Iron Works, of Providence, R. I. These windlasses were horizontal with an inclined engine, and were hung, by means of brackets, from the underside of the main deck.

While the writer was connected with the American Ship Windlass Company as chief draughtsman and superintendent, the types of windlasses shown in Figs. 5, 16 and 17 were designed. The windlass illustrated in Fig. 5 is used on the United States battleships

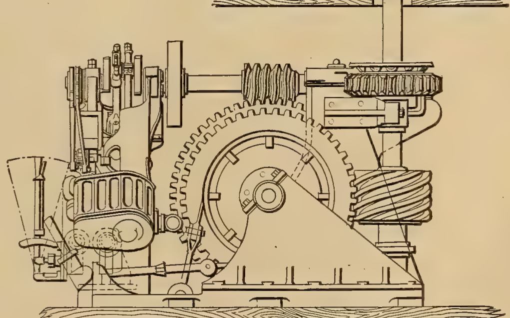


FIG. 14. SIDE VIEW OF WINDLASS SHOWN IN FIG. 12.

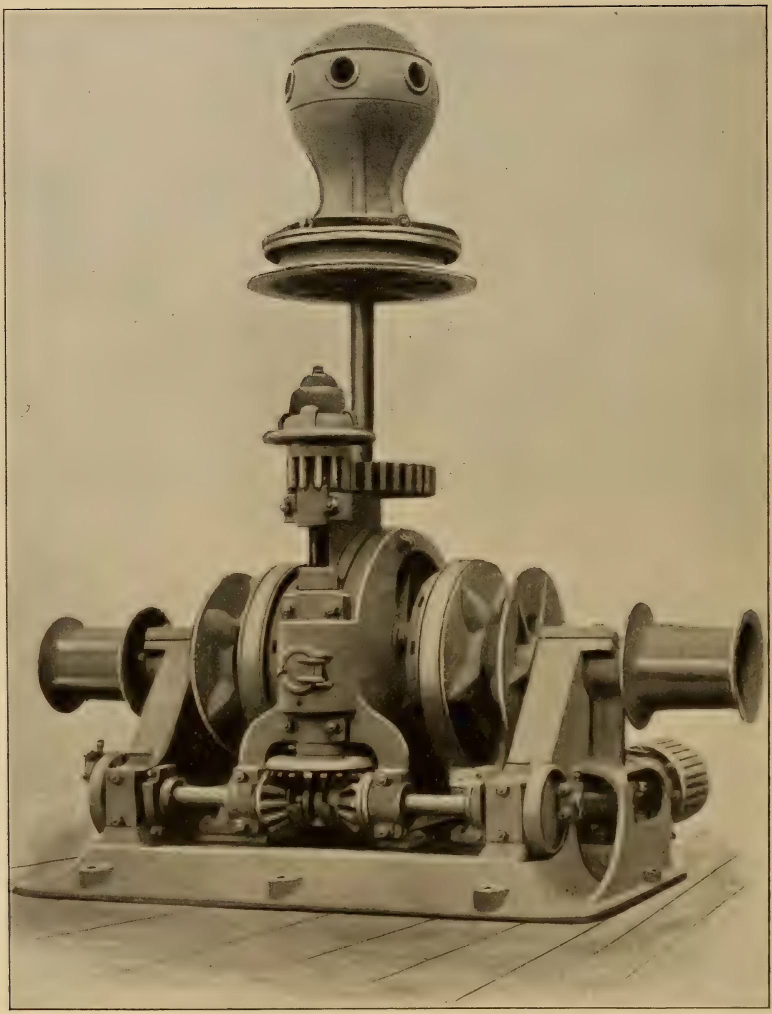


FIG. 15. STEAM CAPSTAN WINDLASS, MADE BY THE GLOBE IRON WORKS CO., CLEVELAND, O., U. S. A.

"Indiana" and "Massachusetts." It is of the steam pump brake type, the brakes working from the deck below the windlass.

The windlass engine is double, with cylinders 15 inches in diameter by 14 inches stroke, and having a cut bronze worm on the crank shaft, driving a cut cast steel worm wheel fitted on the windlass shaft. The worm wheel is 66 inches in diameter, and has 80 teeth, double-thread, giving a ratio of 40 to 1. The weight of the windlass is thirty-five tons.

The following description and cuts of the windlass and captans used on the American Line steamers "St. Louis" and "St. Paul" were taken from *Engineering* of recent date. On each vessel there are a windlass, three power and four speed capstans, one windlass engine, with cylinders 16 inches in diameter by 14 inches stroke, and two capstan engines, with 12 by 14-inch cylinders. Of these, the windlass, one power and two speed capstans are located on the main deck forward, while the windlass engine and

one of the capstan engines which drive them are located on the deck beneath.

The windlass, shown in Figs. 18 and 21, is horizontal and similar in style to the Hyde steam pump brake windlass, with the exception that no provision is made for working the windlass by hand. It is made entirely of steel castings and forgings, and is of sufficient strength to break the 2¾-in. cable. The windlass is driven by worm gearing with a worm wheel keyed fast to the centre of the windlass shaft, the worm being driven by a vertical shaft through a pair of mitre gears connecting the lower end with the crank shaft of the engine. The wheel is of cast steel, and the worm of phosphor-bronze.

The windlass engine is of the inverted vertical type with two cylinders, each 16 inches in diameter by 14 inches stroke, and is capable of exerting 600 horse-power. In case of an accident to the windlass engine, it can be disconnected by means of a clutch at the lower end of the vertical shaft of the windlass, and the latter may be driven from the forward capstan engine through the spur and bevel gears shown.

The worm and gear which drive the capstan are, as in the case of the windlass gearing, machine cut, and are of the hour-glass type, the thrust bearing being arranged so that the thrust rings and worms run in a bath of oil. All these machines were constructed by the Bath Iron Works, Limited, Bath, Maine, U. S. A.

A. Betts Brown, of Brown Brothers & Co., Edinburgh, has brought out more new designs in hydraulic auxiliary machinery for use on shipboard than any other one man. The motor for driving the windlass of the steamer "New York" is of his system. One of the most persistent windlass inventors in Great Britain is William H. Harfield, of London.

The Harfield type of windlass is represented on board the White Star Line Steamship "Majestic" by one of his best make. It is a spur-geared steam driven windlass. The chains used are 3 inches in diameter. The same size

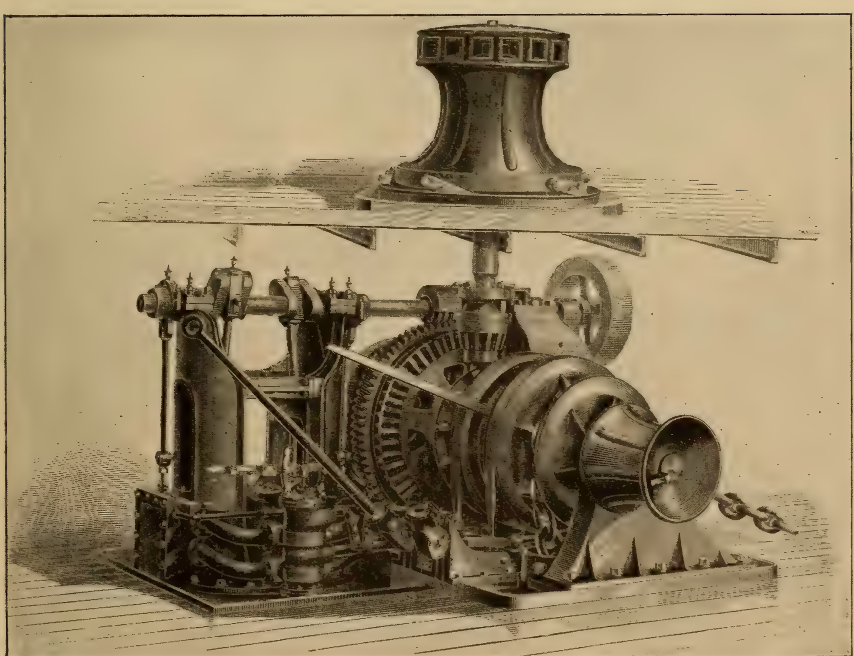


FIG 16. A NAVAL STEAM CAPSTAN WINDLASS, MADE BY THE AMERICAN SHIP WINDLASS CO.

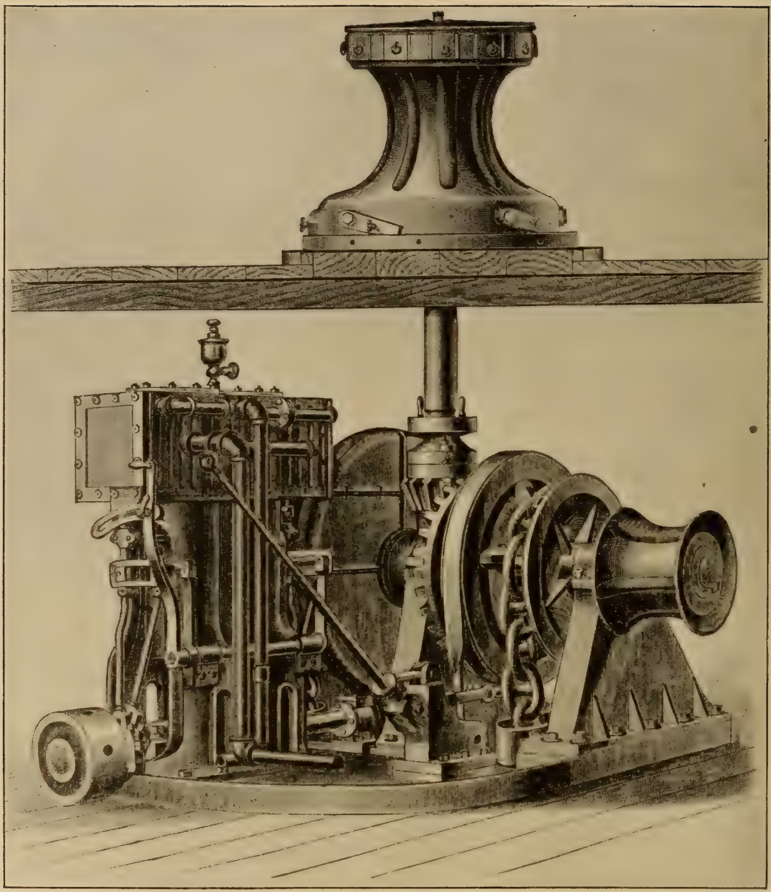


FIG. 17. ANOTHER NAVAL STEAM CAPSTAN WINDLASS MADE BY THE AMERICAN SHIP WINDLASS CO.

was used on the "Great Eastern." In the early English form of iron windlass the cable was taken on the underside of the windlass, then over the wild-cat, around a projection of the side-bitt, and aft to the deck-pipe. This method retained a feature of the capstan, and it is still employed in the Harfield windlass.

Messrs. Clarke, Chapman & Co., of Gates-head-on-Tyne, and Messrs. Emerson, Walker & Thompson Brothers, of London, build a large proportion of the windlasses used on the Atlantic liners and other first-class ships. The pump-brake windlasses of these two firms are very similar in construction. An Emerson-Walker make is shown in Fig. 20.

The Clarke-Chapman steam capstan windlass is represented in Fig. 24. The windlass and engines are precisely similar to their pump-brake type, excepting that the engine is here arranged to drive a capstan standing directly over the windlass on the deck above, and the capstan, being arranged to work the windlass by manual power, dispenses with the lever purchase arrangement.

Fig. 25 shows the standard arrangement of windlass gear made by Messrs. Napier Bros., of Glasgow. A capstan is placed either forward or on the upper deck. In the arrangement of cable and warping gear fitted on board H. M. second-class cruisers "Venus," "Di-

FIG. 18. STEAM WINDLASSES AND CAPSTANS OF THE AMERICAN LINE STEAMER "ST. LOUIS," BUILT BY THE BATH IRON WORKS.

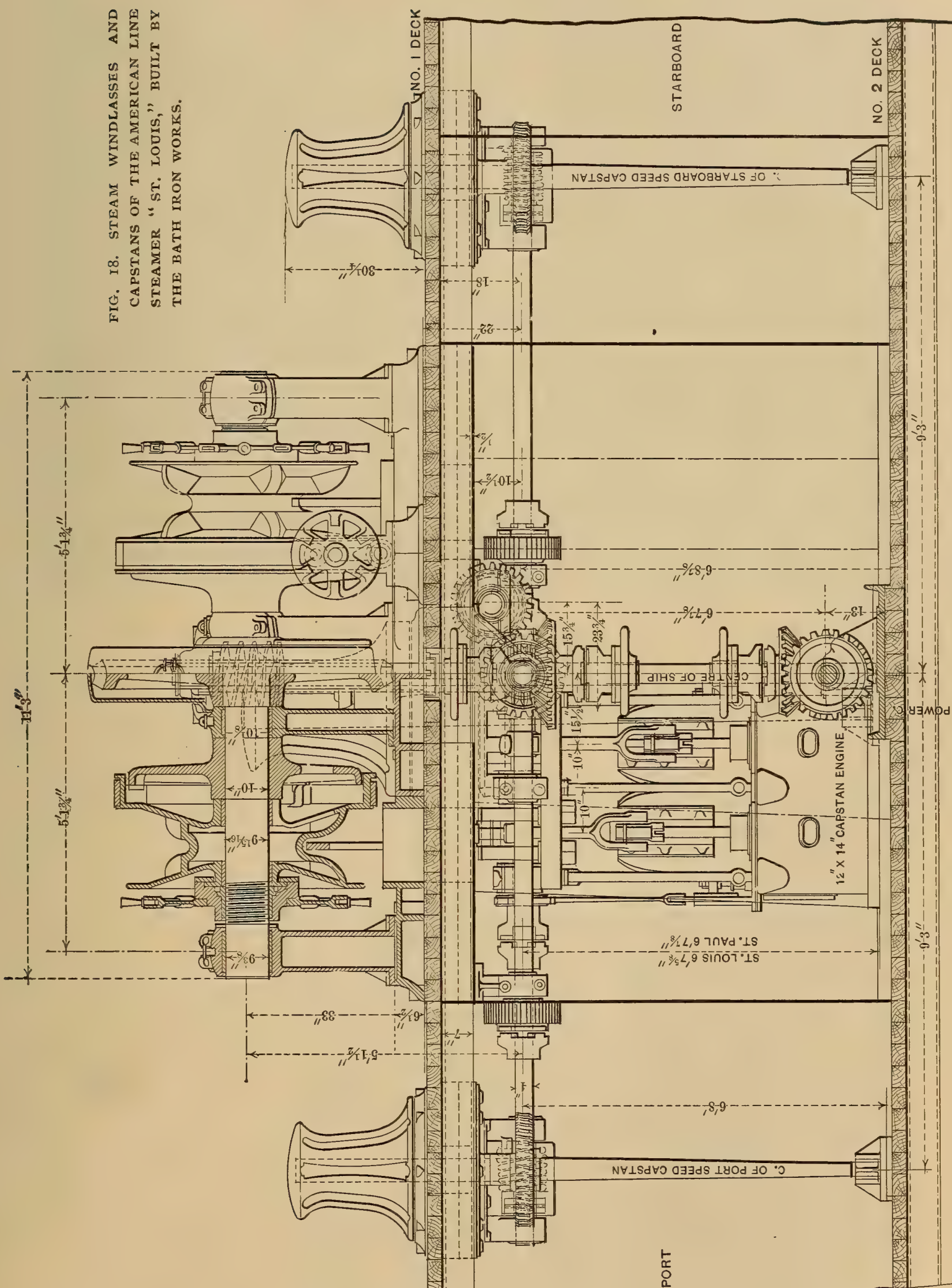


FIG. 19. VIEW OF WINDLASS ON THE AMERICAN LINE STEAMER "ST. LOUIS," LOOKING AFT.

ana," "Dido," and "Iris," the windlass is of the horizontal type, driven through spur gearing by a double engine with inverted cylinders. It has two sets of gearing for warping and catting quickly or slowly with greater power if required. The cable wheels are fitted with a slow motion, heavily geared, to lift the anchors.

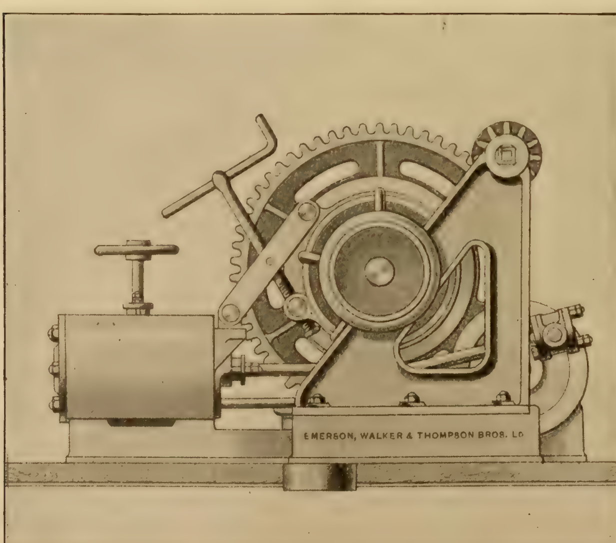


FIG. 20. WINDLASS MADE BY MESSRS. EMERSON, WALKER & THOMPSON BROS., LTD., LONDON.

The vertical arrangement of capstan and windlass gear designed by Messrs. Napier Brothers, and adopted by the British Admiralty for their torpedo-boat destroyers is simple in construction and very light. Worm gearing is used and the outfits can be worked by steam or hand. They have reversing valves and self-holding brakes. The warping is done

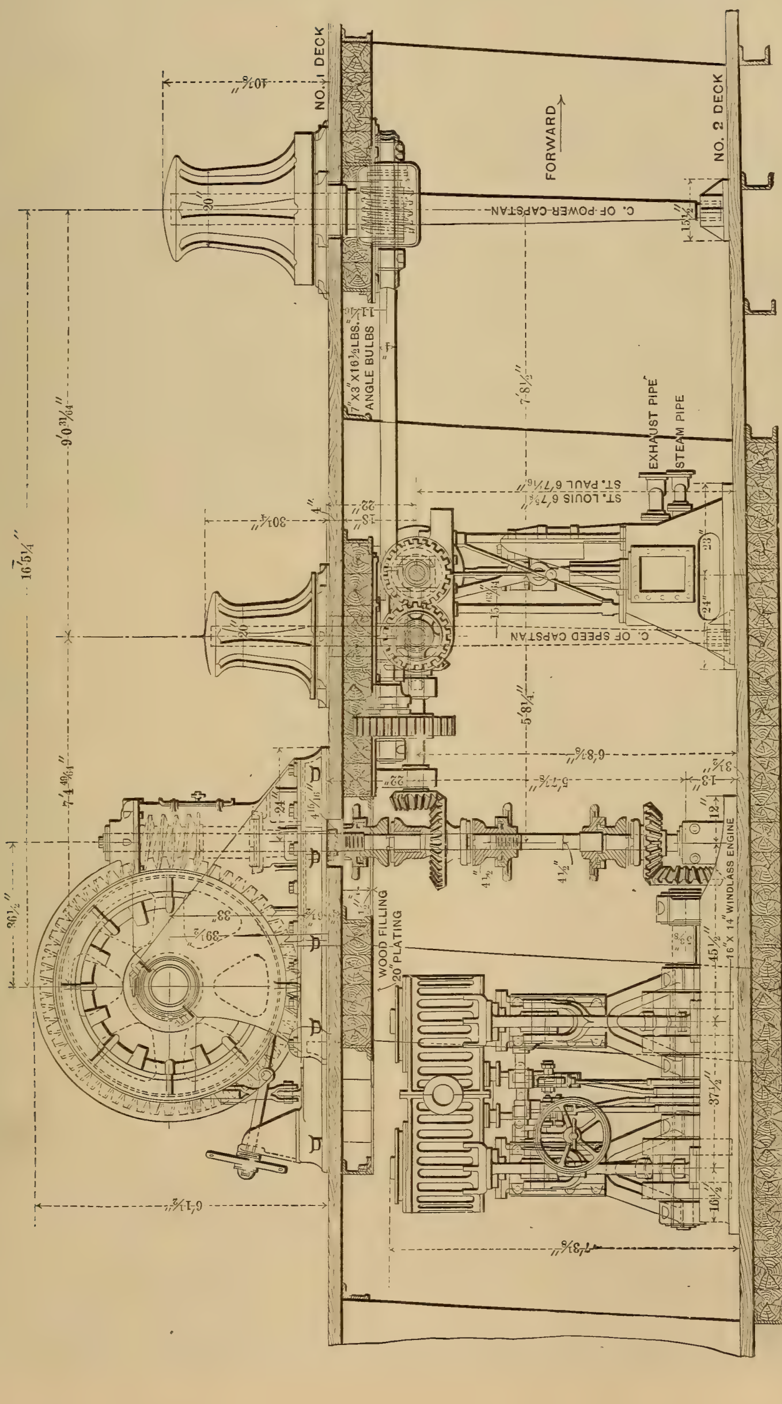


FIG. 21. ELEVATION OF THE WINDLASSES AND CAPSTANS ON THE STEAMER "ST. LOUIS."

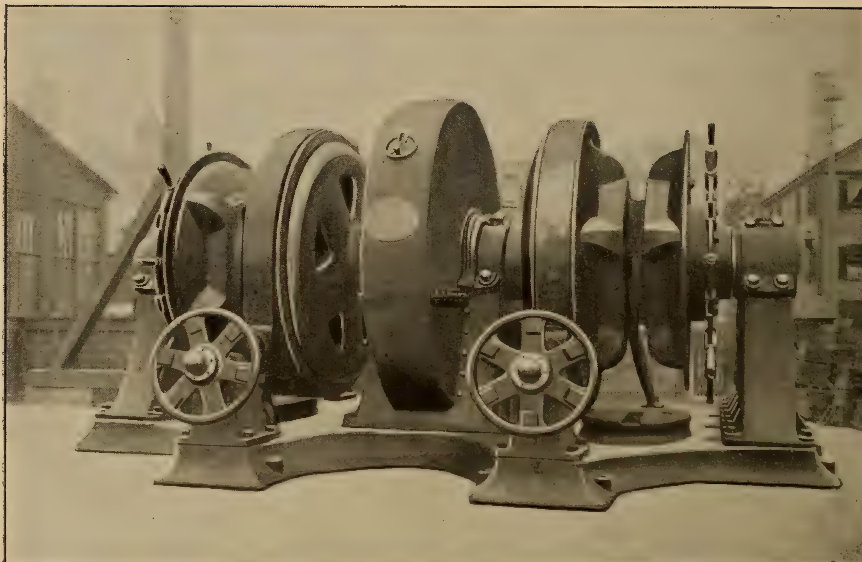


FIG. 22. VIEW OF WINDLASS OF THE AMERICAN LINE STEAMERS "ST. LOUIS AND "ST. PAUL," BUILT BY THE BATH IRON WORKS, BATH, ME, U. S. A.

FIG. 23. VIEW OF THE WINDLASS ON BOARD THE AMERICAN LINE STEAMER "NEW YORK"

by a tapered groove, turned on the upper part of the cable-wheel for the rope.

The windlasses of the Cunard steamships "Campania" and "Lucania" were supplied by Messrs. Napier Brothers, and, as described in *Engineering*, shows a vertical section of the shafting and gearing from the engines to the cable-wheels.

The arrangement, as shown, is for two cable wheels, which can be worked independently of each other, or coupled together. The vertical shaft from the

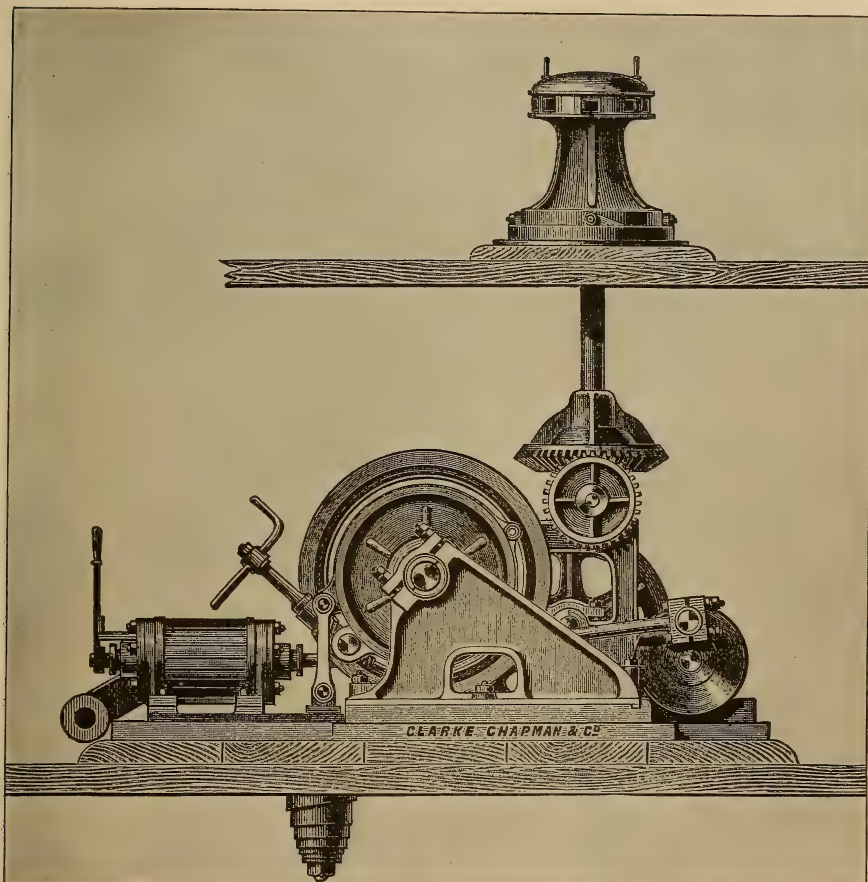


FIG. 24. WINDLASS MADE BY MESSRS. CLARKE, CHAPMAN, PARSONS & CO., GATESHEAD-ON-TYNE, ENGLAND.

are arranged with all the mechanism below, only the hoods projecting above deck. The design adopted is somewhat similar to that used on some of the larger English battleships. The engines are vertical, with cylinders 17 inches in diameter by 14 inches stroke, working with a steam pressure of 150 lbs., and making 150 revolutions. The indicated horse-power is about 600. Fig. 26 engines is geared to a cross-shaft which drives a worm, gearing into a worm wheel on each of the vertical spindles which support and drive the cable wheels. The worms are of phosphor bronze, running in baths of oil, and the worm wheels are of steel. The brake is Napier's patent differential, self-holding brake.

The windlasses to be fitted on board

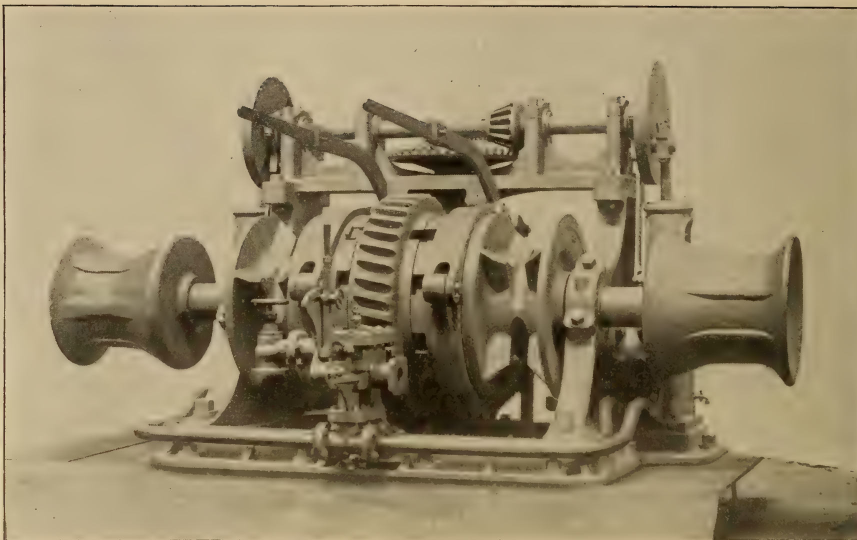


FIG. 25. STANDARD TYPE OF WINDLASS GEAR, MADE BY MESSRS. NAPIER BROS., LTD., GLASGOW, SCOTLAND.

H. M. S. "Powerful," "Terrible," "Mars" and others, are of Messrs. Napier Brothers' make, and are similar in construction to the capstans on the "Campania." Messrs. Muir & Caldwell, of Glasgow; Messrs. Davis & Co., and Samuel Baxter, of London, complete the list of the principal windlass makers of the United Kingdom.

On board yachts the practice has been to use as light a windlass as consistent with the necessary strength. For the larger steam yachts naval architects have preferred the steam capstan

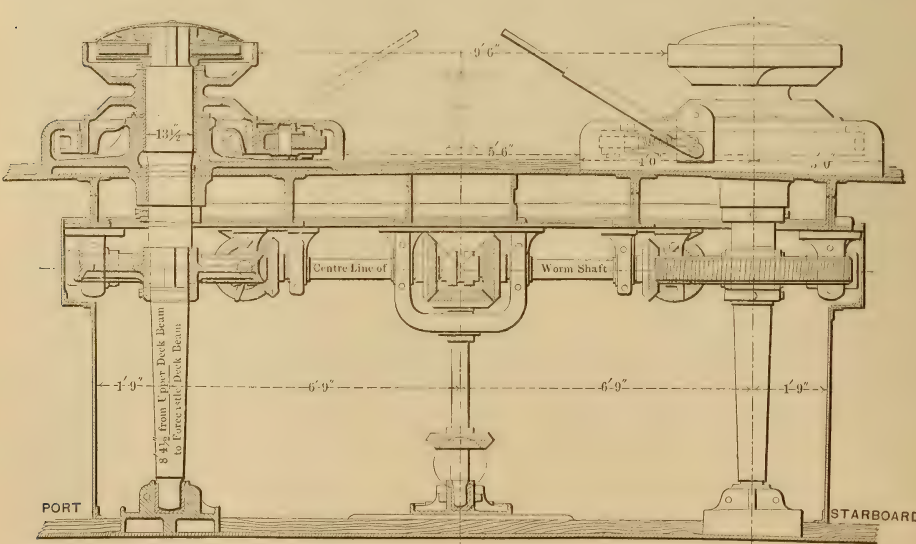


FIG. 26. WINDLASS OF THE CUNARD LINER "CAMPANIA," BUILT BY MESSRS. NAPIER BROS., LTD.

or vertical windlass, but when breadth of beam would admit it, the small steam pump-brake windlass has been employed.

One of the prime essentials of a windlass is that the cable chain shall make a perfect fit on the chain wheel or wildcat. The acting surface of the wheel must be adapted to the figure of the chain, so as to insure a sufficient hold between them. The pitch line of a true chain wheel is a polygon. Each side of the pitch polygon is equal to what may be called the pitch of effective length of a link of the chain. A chain cable consists of oval links, and the pitch of a link which lies flat on the wildcat is equal to its longer internal diameter plus the diameter of the iron, and the pitch of a link which stands edgewise is equal to its longer internal diameter minus the diameter of the iron, so that the pitch polygon has long and short sides alternately. Each short side only of the polygon is provided with a pair of teeth, or lugs, which re-

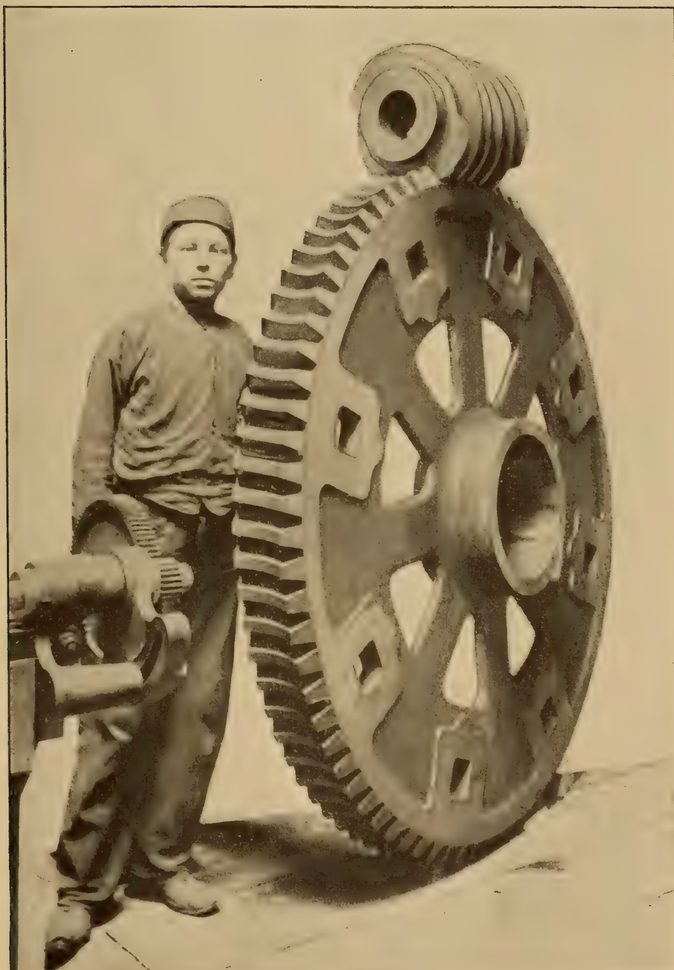


FIG 27. U. S. BATTLESHIP WINDLASS WORM AND WHEEL.

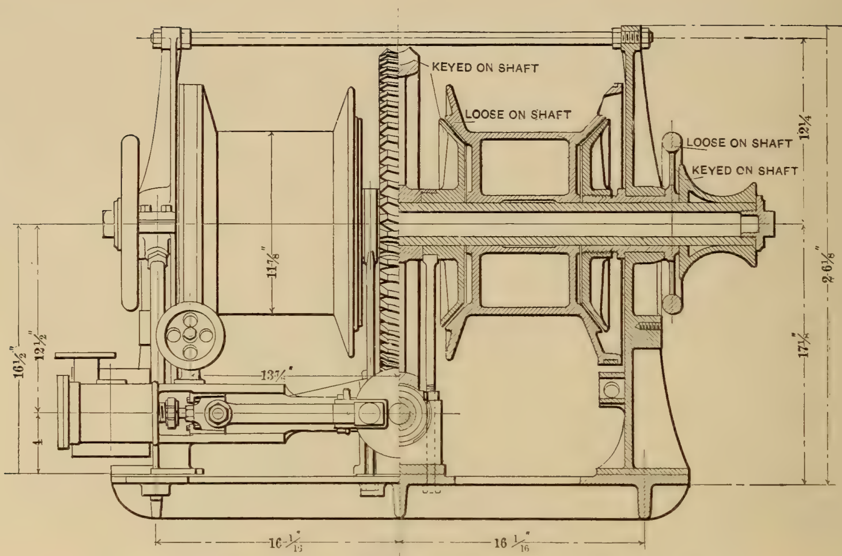


FIG. 28. TORPEDO BOAT ANCHOR WINCH USED IN THE U. S. NAVY.

ceive a link standing edgewise between them, and press against the end of a link that lies flat.

The efficiency of the modern steam windlass depends very greatly upon the efficiency of the worm-gearing driving it, and this is very largely a question of friction. The friction of journals and engine bearings has received considerable attention of late years, and it need not be discussed here, but the subject of worm-gearing in connection with the windlass is an interesting one. In a paper, read before the North-East Coast Institution of Engineers in 1892, Mr. W. C. Mountain, of the firm of Messrs. Scott & Mountain, electrical engineers of Newcastle, says:—

"My first experience of worm-gearing on a large scale was in its application to windlasses and capstans, my firm in Birmingham having built for Messrs. Harfield & Co. some of the largest windlasses afloat, and we found from experience with these windlasses that unless the worm-gearing was well proportioned, and the teeth were very accurately made, the friction was enormous; and, further, that one of the most important points was lubrication. I have recently applied worm-gearing to an electric capstan. In this case the gear was made with a steel worm and cast-iron worm wheel and the result is satisfactory, the lubricant used being black lead and

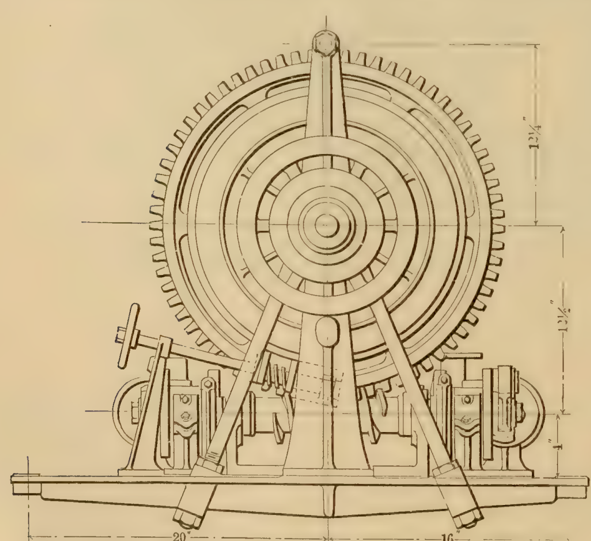


FIG. 29. END VIEW OF WINDLASS SHOWN IN FIG. 28.

tallow.'' Mr. Reckenzaum, in his work on ''Electric Traction,'' says in regard to the construction of his worm-gearing:—''The worm is turned out of a solid piece of steel and is perfectly polished. Its diameter is 6 inches and it has a treble thread of 6 inches pitch. The phosphor-bronze worm wheel has its teeth polished inside; its diameter is 15¼ inches and it has 24 teeth.'' Some of the actual results obtained with spur-gearing and worm-gearing, by Mr. Reckenzaum, are as follows:—With worm-gearing, worm with double thread, speed ratio 1:14, revolutions 1200, the total efficiency in per cent. was from 65 to 69. With spur wheel gearing, speed ratio 1:4 or 5, revolutions 450, the efficiency was from 80 to 83 per cent. The practice adopted by Mr. Reckenzaum in the construction of worm and worm wheel gearing, is used by the Chace Elevator and Manton Windlass Co., of Warren, R. I., in the manufacture of their steam steering engines, and it gives excellent results.

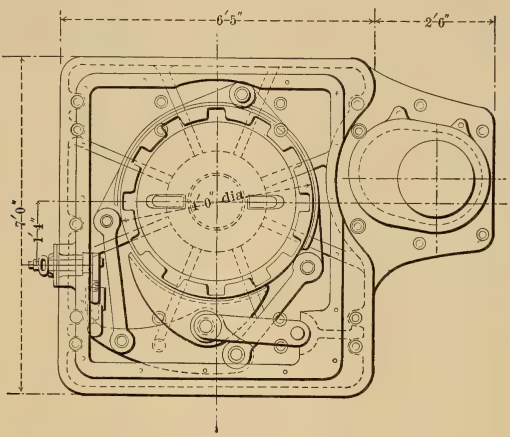


FIG. 30. PLAN OF WINDLASS SHOWN IN FIG. 26.

The Albro system of worm-gearing has been in use a few years, and it has met with considerable favour. This gearing is manufactured by the Morse-Williams Co. and the Albro-Clem Elevator Co., of Philadelphia. It is in use in nearly every one of the windlasses on the ships of the U. S. Navy. It is illustrated in Fig. 27, made from a photograph taken of the worm and wheel of a windlass constructed for one of the battle ships. Both the teeth of the worm and of the wheel are of a particular form and are machine cut. The efficiency of this worm-gearing is shown in the chart reproduced in Fig. 31.

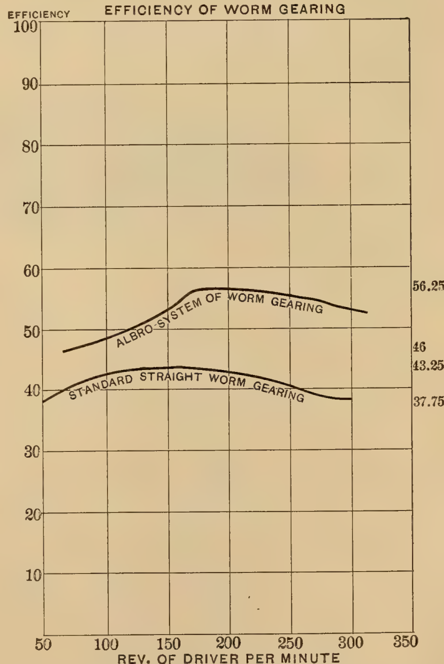
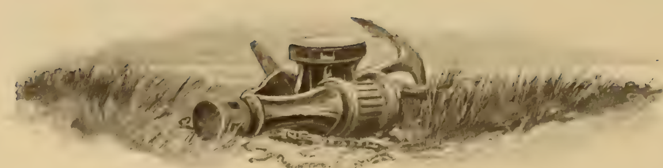


FIG. 31. DIAGRAM ILLUSTRATING THE EFFICIENCY OF WORM GEARING.

Mr. Albro informed the writer that he has since secured better results than here recorded.

It is the usual practice to design windlasses and capstans, so that the worm shaft will run from 200 to 300 revolutions per minute with their normal load, and the best results are obtained at these speeds. Worm-geared windlasses are the favourite type; they are not only noiseless, but take up very little space compared with spur-geared machines. The losses by friction are reduced by correctly machining the teeth, keeping the diameters large, and particularly by running them in a bath of thick oil.

Possibly the windlass of the future may be electrically driven, but thus far the electric motor, in this line at least, has not proved itself a formidable competitor of the steam engine. The modern steam windlass takes in the cable chain with its anchor, at the rate of from 8 to 10 fathoms per minute, a creditable performance, indeed, compared with old time practice when "long pulls and strong pulls," and many of them, were needed to bring an anchor clear.



POWER CONSUMPTION ON ELECTRIC RAILWAYS.

By A. K. Baylor.

THE subject of power consumption on electric railways seems to naturally divide itself into two parts:—First, the apparatus itself, its efficiency and general construction; second, the handling of apparatus. Properly, a consideration of this subject should start with the coal pile, but it is proposed here to consider it merely in its relation to the electrical apparatus, taking the power as it comes from the engine shaft.

One of the first questions bearing on the efficiency of the generating plant that must be considered is whether direct-connected or belt-driven generators are to be used. In a paper recently read before the Pennsylvania Street Railway Association, the writer pointed out that the experience of the last two or three years has shown direct connection to have, in most cases, everything in its favour, and that where land values are high and the units large, these two points alone will dictate the choice of the type of machine.

It was at first supposed that the great fluctuation of load, inevitable in railway work, would introduce a serious menace to the unit (*i. e.*, the engine and generator) when the two were rigidly connected; but this has been shown by repeated experience to be a negligible factor when a properly proportioned flywheel is introduced between engine and armature.

In comparing the two types of machines, the first consideration is apt to be the relative cost. As a direct-coupled generator is usually designed to give a certain output while running at slower speed than a belted generator for equivalent output, it must be large and cost more than the belted machine. From this difference in cost, however, must be deducted the expense of belts, and several other money-saving features must be considered.

The direct-connected machine takes less room, saving land and permitting the use of a smaller building. Only one foundation is necessary, instead of two, and although the one foundation must be larger than either of the two necessary for a belted unit of equal power, it will usually cost less than the sum of the two.

Furthermore, there are fewer bearings and wearing parts to care for, and last, but not least, a saving in efficiency of from 5 to 6 per cent., according to the proportion of load on the generator. This difference in percentage is due to the fact that the least possible friction loss, due to belting, is in the vicinity of 4 or 5 per cent., and even if this minimum be preserved at full load, it becomes about 8 or 10 per cent. when the generator is running at half load. These considerations will usually effect a decision in favour of direct coupling, unless they are offset by a saving in interest charges due to an unusually low-priced belted generator.

The next point to be considered seems to be the proper division of the plant into units. Generally speaking, perhaps the best investment is made by

the installation of three units of equal size, two of which are capable of carrying the full load. This permits efficient running at half load and full load, and leaves one unit always in reserve. It is, of course, desirable for the sake of efficiency and consequent economy of power to run all the working machines as near full load as possible, and to keep "on top" of the efficiency curve, and, with this object in view, some roads have made a division of power into, say, two large units, each equal to one-half the full load and one small one equal to one-quarter load. This permits full load running practically all the time, as combinations of these machines will give one-quarter load, one-half, three-quarter and full load; but in case one of the large units gives out, the remaining one-half and one-quarter unit will have to be considerably overloaded to handle the full load of the station.

It is interesting to note how daily records of current output by readings taken every few minutes will show the separation of the day into distinct load periods which will repeat themselves with astonishing accuracy from day to day when the same general conditions obtain.

For this reason, and because it is impossible to keep playing the generator units into combinations to fit all these fluctuations, it is necessary to choose a generator at the outset with a good efficiency curve; in other words, a "flat" curve, one which rises to 90 per cent. or thereabouts at a comparatively small load, and gradually rises with the load to a high maximum, running then on a practically horizontal line, until the load becomes excessive.

As contributing to this result, the machines should run without excessive heating, which means ample capacity in conductors, commutators and armature, large radiating surfaces, good ventilation and sufficient bearings.

They must run free from sparking up to reasonable overloads, and must have insulation of sufficient resistance to prevent leakages to ground, and, after all this, they must be kept clean.

Buyers should also remember that the manufacturing companies whose engineers have made these points a matter of special study and have the experience of scores of plants to guide them, ought to be, and are, in a position to judge intelligently of the general proportions best calculated to give a certain result.

The buyers should, therefore, confine their specifications, in a reasonable degree, to a list of conditions to be fulfilled—naming the heating, sparking and overload limits required, with other general features, leaving the means for reaching these ends, *i. e.*, the size of conductors, number of commutator bars, thickness of insulation and the thousand and one details of design which go to make up an efficient machine, to the makers.

A great deal would be gained in this direction if consulting engineers fully realized that unless they have given the matter enough study to qualify them as generator designers, they may, through insisting on some peculiarity of detail and receiving a generator fulfilling their specifications, get a machine inferior to what would have been furnished had the manufacturer been held accountable for results only.

As bearing on the general efficiency of the system, the line should be of ample capacity and of insulation sufficient to withstand the potential at all times. The ground return capacity should, of course, be equal to the overhead feeder. An abundance of overhead copper with bad rail bonding, with perhaps open circuits, is an absurdity. As affecting the life of the motors, the feeders should be distributed to deliver as nearly as possible an even potential all over the line, and while the voltage should not be allowed to drop too low, it also should not be raised to any considerable degree above the normal point, as this puts the motor insulation under undue stress.

On this account, when cars run directly past the power house, the feeders should not attach directly to the line, but should spread in either direction and feed back to this point.

It is evident that when a motor has

become dusty or moistened in service, its insulation resistance is reduced, and any excess in potential above its safe limit will result in punctures of the winding and other leakages to ground; whereas, if the pressure be kept inside this limit, if only by a few volts, the bulk of such trouble may be avoided.

Of course, the motor is another factor of prime importance in the economy of power, and what has been said under generators regarding efficiency will apply in a general way here. A motor should be as light as is consistent with strength and power, and should be compact and protected by its frame.

The most important consideration in the purchase of motors may be safely said to be cost of maintenance, but this has no direct bearing on the economy of power, much as it has to do with economy of operation.

As a power saver, the most important part of the car equipment is the controller. The time has gone by when it was necessary to draw comparisons between rheostatic and series—parallel control in considering equipments; yet a good many lines are operating rheostatic controllers without apparently appreciating the loss they are sustaining. Aside from the out-and-out saving in power, by the use of series parallel control, which amounts to a clean 25 to 40 per cent., according to the series, it should be remembered that the necessary generating plant for operating with such controllers is much less than that required for the same car service under rheostatic control, not only because of the average economy of power, but because the momentary fluctuations of load, which must be taken care of, are much less violent, and this latter condition holds good in any case, even for a high-speed road, making few stops, and where the motors are kept in multiple so much of the time that the average power consumed is practically the same for both methods of control.

Another practical advantage is found in the possibility of running all the cars at half speed in case of the disabling of half the power house capacity. This is an important consideration, for instance, on a stormy day, perhaps during a snow storm, when the first desire of patrons is to get aboard cars in large numbers, away from the weather and to be carried to their destination. At such a time the number of minutes consumed in getting there is usually a secondary consideration.

Tracing up the subject of operation at the power house, one of the most effective economies is the use of recording wattmeters registering the load continuously.

By this means, and in connection with readings on individual cars, load curves may be established, representing fairly (by the division of the day into load periods, as mentioned above, and the current output during those periods) the power which should be consumed to handle a given traffic. In this way a careful and intelligent comparison may be drawn between different days in a season and between days of similar character.

Wattmeter readings on separate cars are of especial importance, establishing, as they do, for the unit what the station readings show for the whole system. Repetitions under all conditions will show whether a certain car should consume 800 or 900 or some other number of watt-hours in running a mile, and any sudden or wide variation to-morrow from the standard load readings of to-day and yesterday will indicate a leakage of some sort and attract prompt attention. Without such a system of checks in the delivery of current, there is nothing but the sluggish coal pile to betray any irregularity in power consumption.

In addition to these guards, a recording voltmeter should be used at the station, or a voltage record kept at very frequent intervals. With due allowance for over-compounding, the theoretical record would be a circle, and in practice, with a fairly constant load, the record should approach this standard. If the voltage undergo wide fluctuations, comparing different times of the day, the generator is faulty, or the station man is negligent, and in either case the motors suffer, and they

not only require a greater average current to do a given work at reduced voltage, but they will consume more watts in doing it.

A very great factor in saving power is the degree of intelligence of the motormen. They are too often put upon cars with scarcely any preparation and are then practically left to their own devices, and naturally handle their cars uneconomically. They will often move the controller handle around the dial without regard to the notches, passing into No. 2 before acceleration of the first position has been felt, and so on to Nos. 3 and 4. It sometimes practically amounts to throwing the handle immediately into the first position. As far as economy of power is concerned, such men might almost as well have rheostatic controllers. The pity of it is, too, that, as a rule, the men are not to blame, never having received proper instructions.

A valuable aid in the education of motormen is the use of an ammeter in the motor circuit, in plain sight, so that during their run the men can see the fluctuations of the instrument and note the results of incorrect handling as compared with the right method.

The plan followed by Mr. Know, of the Chicago City Railway, is certainly an excellent one. He has printed curves, laid upon one plot, comparing the current fluctuations with right and wrong methods of starting, posted around the car barns and employees' rooms as a graphic object lesson, which has resulted in an economy of power.

Further than this, motormen should be instructed in the car circuits, with diagrams showing the connections at each position of the controller. With this knowledge a conscientious man would involuntarily make an effort in the right direction.

Another great coal consumer is the brake. A great amount of power is wasted by men who throw their controllers into contact before thoroughly releasing brakes, even when there is no danger of backing. They also throw on the brake before throwing off the power.

Very few men understand or attempt to use the momentum of their car to advantage. They will run with power on close up to a leading car and then apply brakes, when they might coast many feet, using no current whatever. This momentum may also be used to advantage on curves, switches or whereever there is unusual resistance.

The careful scheduling of cars with respect to grades may be an important economy, and although it is a complicated problem, it is worthy of more attention than it is usually given.

Care should be taken to keep bearings and running gear in good condition and to maintain track gauges. The wheels upon any truck should be made of the same diameter (a precaution frequently overlooked) to permit the motors to wear in perfect unison.

A full consideration of this heading leads into every branch of the operation of electric railways, and although the efficiencies of apparatus and the direct handling of it are the first things to consider, every fault in system or operation is directly or indirectly an attack on the coal pile.

THOMAS NEWCOMEN AND HIS WORK.

By William Fletcher.

NEWCOMEN is one of the inventors of the steam engine whose services have been all too scantily recognized. We are willing to admit that many pages of text books on the steam engine are very justly devoted to the detailed description of Boulton's and Watt's fire engines, and, yet, the fact remains that the more obscure inventors previous to Watt's day are often overlooked. Newcomen shares this fate among the rest.

Watt has, indeed, more than once been designated the inventor of the steam engine, though this statement is very far from the truth, for many of Newcomen's atmospheric engines were successfully used for draining mines before Watt devoted any attention to the steam engine. Some of these continued to work during Watt's career, and, strange as it may appear, there are some still at work. Watt has had many biographers ; Newcomen has not had one. The only books that gave a just estimate of Newcomen's inventions have long since been out of print.

The object of this article therefore is to bring to the front the chief inventions of this old-time steam engine builder, who is all but forgotten by those who have been richly benefited by his useful work. Without wishing to detract from the great honour awarded to James Watt, the writer holds that among those who did much to bring the steam engine to its present standard of perfection, foremost places should be given to Thomas Newcomen and his partner, John Cawley.

If we consider the constructive difficulties with which Newcomen had to contend, we shall see every cause for admiration. To realize the true position in which Newcomen was placed, let us imagine a modern village blacksmith undertaking to construct and erect a large pumping engine. No lathes or boring machines were available, and what the castings in those days were like, anyone who visits the Patent Museum at South Kensington can see for himself. The best evidence that Newcomen was no ordinary man, and that he really achieved a great work, is found in the fact that his system has possessed vitality enough to prolong its existence to this moment. Invented in 1711, the Newcomen engine is found at work in 1895. What other original invention can be pointed out which has been worked with little or no intermission for a period of at least 150 years? Modern steam engines are worn out and consigned to the scrap heap in a third of that time.

Respecting Newcomen's skill as a blacksmith, Mr. Hyde Clarke says :—"In those days the country smith represented what was afterwards dignified as millwright. He was the local engineer, and did all such work as the millwright and engineer now perform. In the reign of Charles I., the Blacksmith's Company of London opposed the incorporation of the Clockmaker's Company, on the ground that clockmaking was a part of the business of the blacksmith. They were not without justification for this, for some of the founders of the Clockmaker's Company are designated as smiths. Many old church clocks were really the work of the venerable smith."

The early history of engineering brings to light the names of some ingenious smiths, and Newcomen stands foremost amongst this respectable class of tradesmen and mechanics. The

steam engine was little better than a toy previous to the time of Savery, Newcomen, and Cawley, and these three working mechanics brought it to perfection, and harnessed it to useful work.

Admirable as Savery's engine was, when compared to anything that had been employed to raise water before its invention, many serious objections lay against its usefulness. The greatest height to which it could raise water was from 300 to 350 feet. Four or five of Savery's engines would be required to drain some of the mines at that time,—one engine delivering to the other ; but such a complication of engines was not to be thought of. In one case only do we read of Savery's engine being put to work in a mine. We have accounts of several engines being erected for very light work, but whenever Savery attempted to apply his engine to heavy work he failed. In 1706, we read of one of Savery's engines, which was liable to so many disorders, owing to the great steam pressure required to do the work, that it was looked upon as a useless piece of work and was rejected.

Newcomen lived in the town of Dartmouth, in Devonshire, England. The place and time of his birth and death are not known, and not a single item of information respecting his personal history can be gleaned from any of the old works on the steam engine. From the respectful manner, however, in which Dr. Allen mentions "his very good friend, the ever-memorable Mr. Newcomen, whose death he very much regretted," we may conclude that he enjoyed that rank in society and regard of men of merit to which his admirable inventions gave him so strong a claim. All that is known of John Cawley, Newcomen's partner and townsman, is that he was a plumber and glazier. He probably rendered financial help, for Cawley does not appear to have given much assistance in the erection or the working of the engines.

If we have few particulars of Newcomen's life, however, we have many interesting specimens of his work, and if our work reveals our true character, then Newcomen must have possessed an excellent spirit, for few engineers have done more good work than he achieved. It is stated on the best authority that Newcomen's engine was invented before Savery applied for a patent. Savery was fortunate enough to obtain a patent for his apparatus in 1698, though it was not until 1710 that he succeeded in erecting a successful engine for light work. No patent appears to have been taken out by Newcomen.

All the available facts lead to the inference that Newcomen was of a modest

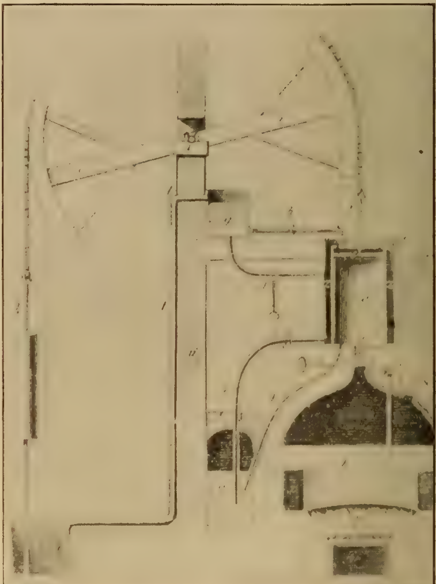


FIG. I. NEWCOMEN'S EARLIEST ENGINE.

FROM AN OLD ENGRAVING.

and retiring disposition. His connection with the Society of Friends would not allow him to enter into strife with Savery as to priority of invention, or as to the superiority of his own engine. To prevent any contention, Newcomen calmly allowed Savery to reap where he had not sown. Handicapped in this manner, the wonder is that Newcomen accomplished so much, for we do not read that Savery or Cawley

rendered much aid in the construction of the engines. The early examples were all the handiwork of Newcomen himself.

He first made the experiment of introducing steam under a piston moving in a cylinder, and formed a vacuum by condensing the steam by the application of cold water on the outside of the cylinder, so that the weight of the atmosphere pressed the piston to the bottom. This was the first form of the atmospheric engine,—the simplest and the most powerful machine that had hitherto been constructed. Fig. 1 shows a section of Newcomen's earliest engine. The steam was generated in a boiler *b*, and admitted into a cylinder *a*, under the steam piston *s*, attached by a rod to a beam moving on a fulcrum or axis. The cylinder was fitted with an outer casing, as shown, and this outer cylinder was connected by a pipe to a reservoir *g*, containing cold water. Another pipe, proceeding from its lower end, was inserted into a well.

The piston being in the position shown in the illustration, and the cylinder being filled with steam through the pipe *q*, the cock *d* is turned, which shuts off communication between the cylinder and the boiler. By opening the cock *f*, cold water is now allowed to flow from the reservoir *g* into the annular space around the cylinder. This condenses the steam, and forms a vacuum beneath the piston. The pressure of the atmosphere, meeting with no resistance, forces the piston to the bottom of the cylinder. By this movement the end of the beam, attached to the piston, is depressed, and the other end of the lever, to which the pump rod is fixed, is raised, and draws up the water in the pump barrel.

When the piston has arrived at the bottom of the cylinder, the cock *d* is turned, which again allows the steam to enter the cylinder. In this engine the steam pressure was equal only to the pressure of the atmosphere, and the piston had to be raised to the top of the cylinder by other means. This was effected by a counterpoise *m*. During this operation the cock *f* was shut, and the cock *e* open, so that the heated water in the outer cylinder escaped into the well. The small quantity of water, formed in the cylinder *a* by the condensation of the steam, was allowed to fall into the same receptacle.

The cylinder being a second time filled with steam, the cock *f* was opened, cold water flowed from the reservoir *g* into *z*, and the steam under the piston was again condensed. The pressure of the atmosphere a second time having the preponderance, the piston was depressed, and the pump rod at the opposite end of the beam was elevated, lifting the column of water in the pump barrel as before. By closing the cock *f* and opening *e* and *d*, the counterpoise *m* again acted to raise the piston, and the operation could thus be indefinitely repeated. The cylinder was made of brass. A pipe from the reservoir *g* allowed a small quantity of water to flow on to the top of the piston to keep it air-tight,—a contrivance first used by Newcomen.

In the year 1711 the inventors made proposals to draw water from a mine at Griff, in Warwickshire, but the scheme did not meet with any encouragement. In March, 1712, however, Newcomen succeeded in obtaining a contract to draw water from a mine in Wolverhampton, but after the engine was erected, he had some difficulty in making it raise any water. The pumps were at fault, but, being near Birmingham, he obtained some assistance from ingenious workmen from that town, after which the engine operated satisfactorily.

It would appear that at the time of the erection of this engine, condensing by injection had not yet been invented. The steam was condensed from the outside of the cylinder as just described. The superior method of condensing by injection, according to Desaguliers, was discovered by accident. "One thing," he says, "is very remarkable. As Newcomen and Cawley were working, they were surprised to see the engine go several strokes, and very quick together, when, after a search,

they found a hole in the piston, which let the cold water in to condense the steam in the inside of the cylinder, whereas before they had done it on the outside."

It will be seen from Fig. 2 that only a very slight alteration in the construction of the engine was required to condense the steam inside the cylinder by injection. When the piston is at the top of the cylinder and the cylinder is filled with steam, the cock *f* is opened and the cold water issues in a jet, and condenses the vapour; a vacuum is rapidly formed beneath the piston, and the pressure of the atmosphere gives a downward motion. The injection water escapes into the well by the pipe *p*. The action of all the parts in Fig. 2 is the same as in Fig. 1, and the same letters in each refer to the same details. The varying lengths of the pump rods required different counterweights to be used for the purpose of adjustment. When the engines were working under light loads, to prevent shocks arising from this cause, the quantity of the injection water was lessened. The piston, like the cylinder, was made of brass, and on the upper side a leather flap was secured, which was kept soft and air-tight by means of an overlying stratum of water, a few inches in depth.

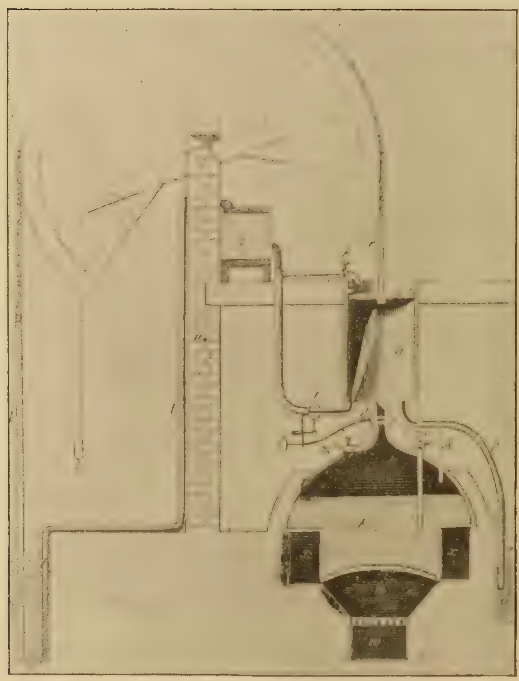


FIG. 2. NEWCOMEN'S INJECTION CONDENSING ENGINE.

FROM AN OLD ENGRAVING.

The early boilers were of copper, and the tops of the boilers were sometimes made of lead. Later, the bottoms of the boilers and the sides were made of wrought iron. The fire circulated through mason-work flues around the sides. The top of the boiler was often covered with a stone slab, on which the cylinder rested. In those early days some boilers were made of granite blocks, held together by iron clamps; and flues of copper, passing through the water, carried the fire and the heated gases.

It is evident that the engine erected at Wolverhampton was automatic, or self-acting, notwithstanding the little story of Humphrey Potter and his catch, that has gone the round of all the books on the steam engine. Of all the ingenious contrivances invented by Newcomen, the self-acting gear was perhaps the most remarkable. By means of this ingenious mechanism the engine was made to work entirely by itself. It was, as it were, provided with hands, by which it opened and closed the steam-valve and injection-cock at the right moment. On the piston arriving at the top of its stroke, the regulator or steam-valve required to be closed, and the injection-cock to be opened immediately afterwards.

The apparatus by which the injection-cock was opened and closed was named from its shape the **F**; and, for a similar reason, that which opened and closed the regulator was called the **Y**. In the earliest form of the self-acting gear, the steam in the boiler regulated the number of strokes made by the engine by

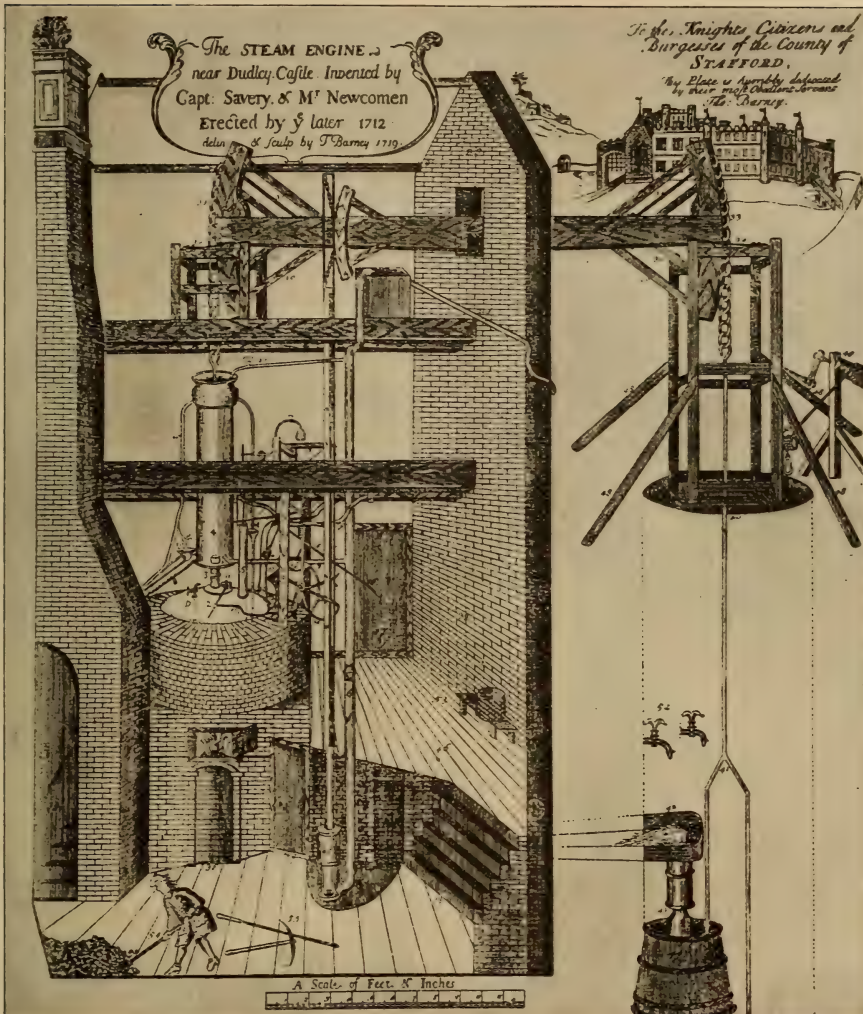


FIG. 3. THE ENGINE NEAR DUDLEY CASTLE.

FROM AN OLD ENGRAVING.

means of a float, resting upon the surface of the water, and from this float a rod was carried upwards and connected to the valve gear, so as to effect the object named.

We must now refer to an exceedingly rare print that was recently brought to light. It represents "The Steam Engine near Dudley Castle, invented by Captain Savery and Mr. Newcomen. Erected by ye latter in 1712." This print is reproduced in Fig. 3. From this illustration we learn the important fact that Newcomen's early engines were self-acting. The story, told in most of the works on the steam engine, respecting boys being employed to open and close the cocks for working the engine, is probably a myth. The date of the invention of the self-acting gear is given as 1718, but this print shows the self-acting gear on an engine erected 6 years earlier. The miners, who had refused to adopt Savery's en-

gines, quickly appreciated the advantages of Newcomen's invention. Many engines were made, and in a few years they were adopted for draining mines in all parts of the British Kingdom.

Mr. Farey gives some particulars of a Newcomen engine, which was erected in 1714, at Austhorpe, in Yorkshire. The cylinder was 23 inches in diameter, and of 6 feet stroke, and made 15 strokes a minute. Fig. 4 shows the type of engine with a cylinder intended for a long stroke. The self-acting valve gear is also clearly shown in this illustration. When this engine was built there were two Newcomen engines at work at Newcastle, and one near Coventry. Several engines were introduced also into collieries in Scotland about this time.

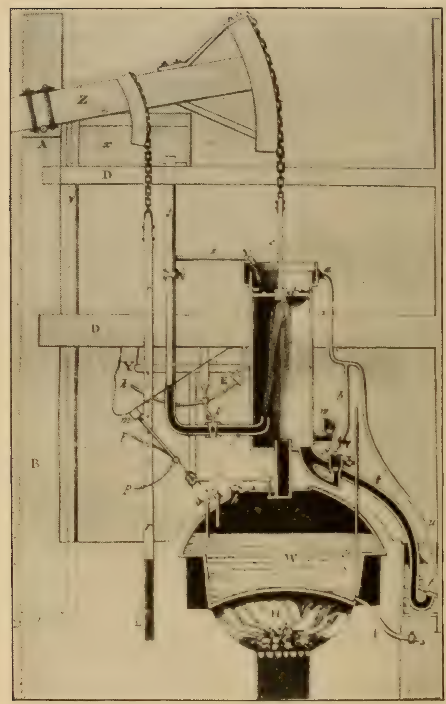


FIG. 4. A LONG-STROKE ENGINE.

FROM AN OLD ENGRAVING.

In 1723, an engine like Fig. 5 was working at Griff, in Warwickshire. The cylinder, which was of brass, was 22 inches in diameter, and eight or nine feet long. The sliding-beam, or plug-rod, was no longer used for raising water, but devoted entirely to the working of the self-acting gear. This gear was of an exceedingly simple type. The engine made sixteen strokes per minute, and worked well with a pressure of one pound of steam above the pressure of the atmosphere. Regarding the performance of this engine, Desaguliers states that "the water was raised from a depth of fifty yards, in three lifts, and as much water was discharged as did before employ more than fifty horses, at an expense of £900 a year; whereas the fire in coals, attendance and repairs, cost about £150 a year." The first Newcomen engine on the Continent of Europe was built by an Englishman at Kônisberg, in Hungary, about 1723.

Newcomen lived to see his invention widely introduced, and on all occasions with the greatest success. Fig. 6 shows an engine which was erected by English engineers at a coal mine at Fresnes, near Condé. The cylinder was 30 inches in diameter. Previous to the erection of this engine, fifty horses and twenty men, working day and night, had been required to raise the water from the mine, whereas the engine, with

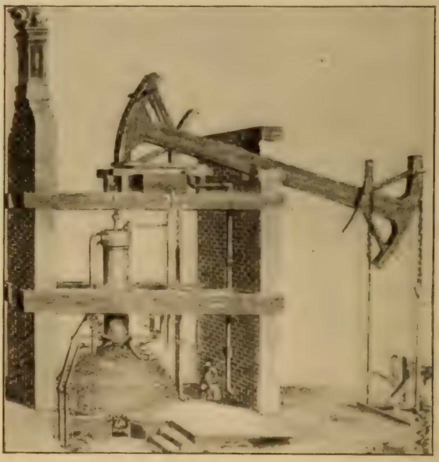


FIG. 5. THE ATMOSPHERIC ENGINE AT GRIFF, 1723.

a single attendant, in forty-eight hours, cleared the colliery of water for a whole week. Belidor says: "We must avow that this is the most marvelous of all machines, and that there is not a single other of which the mechanism has so much resemblance to that of animals. Heat is the cause of its motion; a circulation takes place in its tubes like that of the blood in the veins; it has valves which open and close at the proper moment; it feeds itself; it rejects what it has used, at regular intervals; it draws from its own work everything that it requires for its support."

Before referring to the Newcomen engines built by Smeaton, mention should be made of two models which are still in existence. One is said to have been made by the inventor himself, and by him presented to George III. It is now the property of King's College, London. The model is beautifully made, and is in admirable preservation. Being an example of Newcomen's handiwork, it possesses extreme interest. Respecting the second model, shown in Fig. 8, the London *Engineer* says:

"No one who is in the least familiar with the history of the steam engine can be unaware that it was during the repair of a model of Newcomen's engine that Watt's mind was first directed seriously to the subject of steam. That model has been religiously kept by the University of Glasgow, and the authorities have sent it to South Kensington. It stands in a glass case next to the one which contains the Newcomen model from King's College, and bears the following inscription:—'In 1765, James Watt, in working to repair this model, belonging to the Natural Philosophy class in the University of Glasgow, made the discovery of a separate condenser, which has identified his name with that of the steam engine.' The wood-cut will give an idea of this 'fine plaything,' as Watt called it at first. The cocks, it will be observed, were worked by a bar attached to the main beam. If it were possible to regard this simply as a model which had passed under Watt's hand, it would be looked at with interest; but, considering the stupendous results which had flowed from the train of experiments to which it gave rise, one may well be excused for regarding it with something like veneration."

About the year 1735, the materials used in the construction of Newcomen's

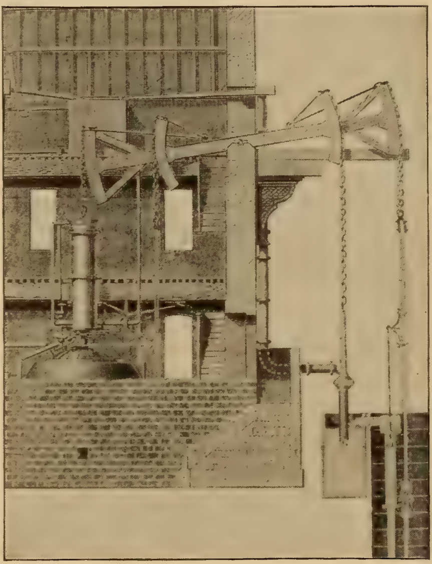


FIG. 6. THE ENGINE AT FRESNES, 1739.

engines underwent a change, owing to the rapid spread of the use of cast-iron, turned out on a large scale by the Coalbrookdale Ironworks. The brass cylinders, copper boilers, and wooden pumps, all became things of the past. The Coalbrookdale Ironworks for a long period continued the chief source from which the supply of the new and cheaper material was obtained. Many atmospheric engines, some of very large size, were built at collieries in the Newcastle-on-Tyne district between the years 1746 to 1776. A large one, built in 1763, is referred to in the local records of Newcastle-on-Tyne in the following terms—"A fire engine cylinder was landed for the use of Walker Colliery, which surpassed everything of the kind which had been seen in the North. The diameter of the bore was 74 inches, and it was 10½ feet in length.

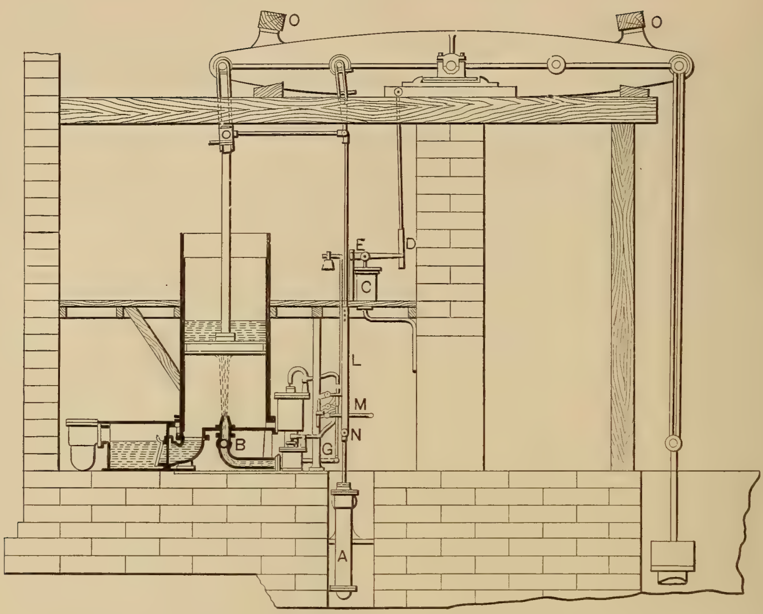


FIG. 7. A NEWCOMEN ENGINE OF 1820

It weighed six tons. The bore was perfectly round and well polished. It was considered a complete piece of work, and did honour to Coalbrookdale Foundry, in Shropshire, where it was manufactured."

This engine was the largest in the North of England, and probably the largest Newcomen engine made. Four large boilers were employed to supply the steam. The tops of the boilers were made of lead, with the exception of the one immediately under the cylinder, the top of which was of copper. The lower part of the boilers were of iron. Hemp was used for packing the piston, and the usual stratum of water was kept on the top of it. The mine was 600 feet deep, and the water was raised in three lifts, and discharged into the river Tyne. Cast-iron was used for the pumps.

We have now reached a period during which the Newcomen engines were being erected rapidly in all parts of Europe. Many makers of these engines had sprung up, but most of the castings appear to have been made by the Coalbrookdale Foundry Company. The celebrated engineer, John Smeaton, was the master builder. He vastly increased the dimensions of the engines and made a few minor improvements. In other respects the engine remained as Newcomen had left it. Dr. Robinson, a contemporary and friend of Watt, said: "Such is the state in which Newcomen's steam engine had continued in use for sixty years, neglected by the philosopher, although it is the most curious object which human ingenuity has yet offered to his contemplation, and abandoned to the efforts of unlettered artists."

While Smeaton was busy erecting and carrying out trials on the Newcomen engines, with a view to their improvement, Watt was also building his engines. It is generally supposed that the atmospheric engine was discarded upon the arrival of the new pumping engine by Watt, but the former held its own for years after Boulton and Watt's engines entered the arena. Is it possible that the Newcomen engines that are at work to-day will actually outlive the few remaining examples of Watt's superior engines?

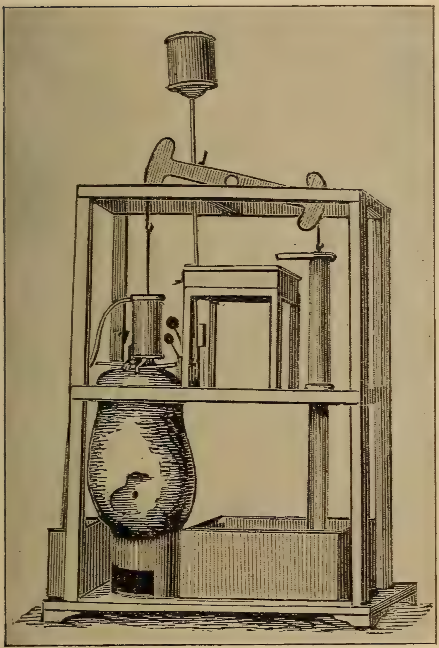


FIG. 8. MODEL OF A NEWCOMEN ENGINE AT THE SOUTH KENSINGTON MUSEUM.

gins. This method of producing continuous circular motion was not very satisfactory.

In 1780 Pickard patented a new method of applying fire engines to the turning of wheels whereby a rotative motion was obtained and the power of the engine was more immediately and fully applied (where motion round an axis was required) than by the intervention of a water wheel. Pickard applied a crank and fly-wheel to a Newcomen engine. Farey, in 1827, said: "About the years 1790 to 1793, when steam mills began to be introduced into all the large manufacturing towns, great numbers of atmospheric engines were made for turning mills, particularly in districts where coal was cheap. These engines answered the purpose to which they were applied, and were used for many years; some of them are still in use." Mr. Thompson, engineer ot Ashover, in Derbyshire, in 1793, took out a patent for a plan of combining two atmospheric cylinders in one engine, so as to produce a double action. Sev-

In 1769 Smeaton obtained a list of one hundred engines which had been erected at collieries in the Newcastle district alone. In 1775 Smeaton built the celebrated Chacewater engine for a mine in Cornwall. This engine, shown in Fig. 9, had a 66-inch cylinder, with a 9-foot stroke, and made nine strokes per minute. There were three boilers, each 15 feet in diameter. The beam of this engine was made of twenty fir deals, as shown in the illustration. We may here remark that the beams were soon after this time made of cast iron. Just a word may be said here respecting Smeaton's method of employing fire engines to raise coal out of pits. The engines were made to raise the water into an elevated cistern, and the coal was drawn up by means of large water wheels. The first of these "water coal-gins" was erected by Smeaton in 1777 for a colliery. It performed the work previously done by sixteen horses and four men with horse-

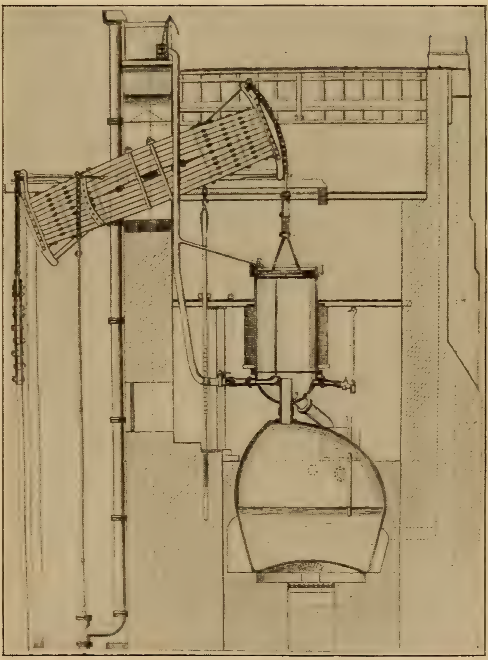


FIG. 9. ATMOSPHERIC ENGINE AT CHACEWATER, 1775.

eral engines were made on this plan, but they were not very successful.

The Newcomen engines at the Farme Colliery, near Rutherglen, are the three best and most remarkable examples of the Newcomen system, of which we have any knowledge. The first engine was erected in 1810. It has a 32-inch cylinder, with a stroke of 5 feet 8 inches, has worked almost constantly since it was put up, and has cost little or nothing for repairs. It is employed for raising coal. One rope draws from a depth of 180 feet, and the other from a depth of 264 feet. The engine, also, until recently, pumped water from a depth of 138 feet with an 8-inch bucket pump. It drew from 150 to 200 tons of coal per day, and pumped for 4 or 5 hours in the 24 on a consumption of 34 cwt. of "dross" coal per 24 hours.

In 1820 the pumping engine shown in Fig. 7 was erected. It has a 60-inch cylinder, with a stroke of 7 feet, and has a cast-iron beam. It worked three sets. The pump in the top set was 120 feet deep, with a 15½-inch bucket; the second was 180 feet deep, with a 12-inch bucket; and the third was 120 feet deep, with a 10-inch bucket, or 420 feet in all. In 1857 certain changes were made in the working of the colliery when the old steam inlet valves were removed and replaced with Cornish double-heat valves.

The third engine at the Farme colliery is used for winding. It draws up 300 tons of coal in ten hours from a depth of 480 feet. Referring to these engines a number of years ago, the *Engineer*, of London, said:—"It may not be out of place to say something concerning the work which Watt really did in improving upon Newcomen's designs. It will be found that almost all Watt's biographers regard his invention of the separate condenser as the chief performance of his life—the most exalted manifestation of his genius. Without wishing to detract from the great merit of this invention, however, we assert that this proposition is founded on an entirely erroneous idea of the conditions which promote economy in the use of steam. No doubt Watt at one time held the same opinion as his subsequent biographers; for he himself, after describing his first well known experiment with a brass syringe and surface condenser of tin-plate, goes on:—'The quantity of steam consumed, and the weights it could raise, were observed, and excepting the non-application of the steam case and the external covering, the invention was complete in so far as regarded the saving of steam and fuel.'

"Here Watt, beyond question, attached an exaggerated value to the separate condenser. He was not aware of the great conducting power of vapour; nor was it indeed understood until long afterwards that the effect of the separate condenser, as far as the temperature of the cylinder was concerned, was just the same as though the cylinder had been prolonged, and the condensed water had not been permitted to strike the piston or the sides of the cylinder. In other words, the Watt condenser is simply an extension of the cylinder, and, as far as wasteful condensation of steam is concerned, the separate condenser does little to promote economy. In practice, the temperature of the inside of an unjacketed cylinder always falls at every stroke to that of the condenser, no matter where the latter may be. In the Newcomen engine, however, the cold injection water was used in profusion, and was allowed to strike the piston and the sides of the cylinder, and to cool down a considerable thickness of metal at each stroke in excess of that which could be cooled down by the conveyance of heat from the cylinder to a separate condenser."

There is an old-time Newcomen pumping engine at a colliery near Bristol, which is at work at the present day. As the pit is fairly dry, the engine is worked only during the night for about two nights a week. A correspondent in the *Engineer* says of it:—"We were conducted to the ancient driver. This individual, who looked fully as old as the engine, but who, in response to sympathetic enquiries, assured us that he was not so 'owld as 'a looked,' led

the way to the engine house door. The cylinder is 6 ft. in diameter, and of about 10 ft. stroke. Water packing is used for the piston, a 2-inch pipe delivering a constant stream of water on to the top side. The beam is a wonderful structure, with a 'horse's head' at each end (the quadrants shown in Fig. 5 are termed horse's heads), the inner end being connected to the three piston rods by means of stout chains. Our guide related how the soundness of the cylinder bottom had been tested more than once by the snapping of these chains, the piston and rods coming down with a crash." This engine is of great age,—probably the oldest engine in existence doing actual work. "The old man had driven it himself since the days when he was a boy so small that he had to stand on a block to reach the valve handles, and his father and grand-father had driven it before him."

We conclude by saying, as we commenced, that Newcomen is entitled to considerably more honour than has been awarded to him for the great work he achieved in the invention and development of the steam engine. In studying his works we have discovered some engines that are so well arranged and constructed, that they bid fair to outlive all other steam engines made by any succeeding inventor, and probably they will be found to possess more vitality than any steam engine ever built by James Watt.

A STEADY PLATFORM AT SEA.

By Beauchamp Tower.

A STEADY platform at sea,—most people who have been the sport of the sad sea waves will be attracted by the subject of this paper. They must not be disappointed, however, in finding that as yet its advantage is enjoyed only by search light projectors, but must hope, as they may, with reason, that before long it will be extended to suffering humanity.

Probably some one, at first sight of the problem, will suggest that this object may be attained without much difficulty by connecting, in some way, the to-be-steadied object with a pendulum, or by converting it into a pendulum by suspending it on a pivot and ballasting heavily below, and he will point to the bowl of the mariner's compass or to the swing table commonly used on board yachts as examples of objects steadied by this means. But if he will look along the top edge of the compass bowl, or the table, at the horizon, he will see that the steadiness thus obtained is of the same order as that of the ship's deck. The ship itself is a pendulum kept upright in still water by ballast, and causes which make it depart from uprightness act with the like effect on pendulums placed on it.

"But, surely, a pendulum hangs perpendicularly in obedience to gravity," says our suggestor, but equally surely the surface of water lies horizontally in obedience to the same law, and this is perfectly true of both so long as gravity is the only force acting upon them. We have only, however, to look at, or feel, the surface of a rough sea to assure ourselves that the surface of water may, when acted on by other forces besides gravity, depart most grievously from the horizontal, and how can we expect a pendulum to hang perpendicularly under circumstances in which the surface of water will not remain horizontal? The particles of water in a wave sway backwards and forwards in a horizontal plane as well as upwards and downwards, and this horizontal motion introduces forces which, compounded

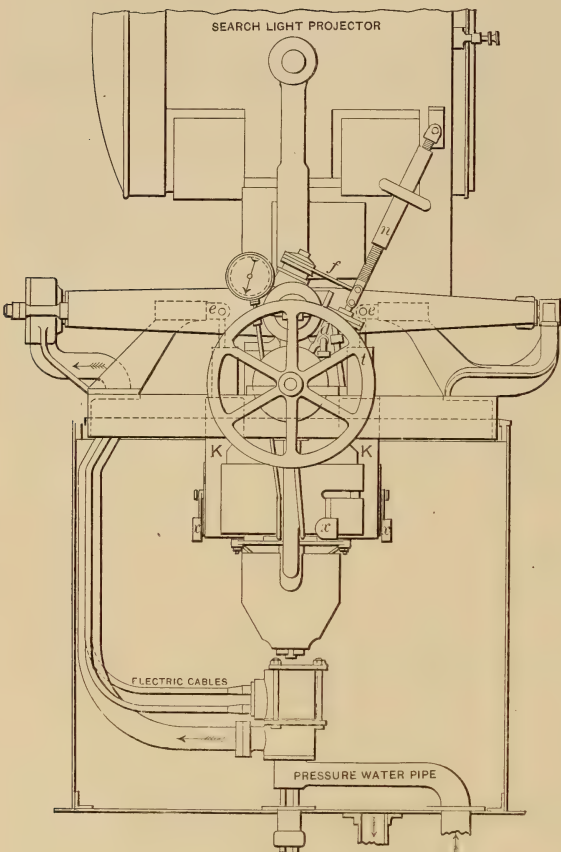


FIG. 1. ELEVATION OF A STEADY PLATFORM.

with gravity, give a false level which departs from the true level as much as the slope of the wave does.

The late Mr. William Froude, in a paper on "The Rolling of Ships," read before the British Institution of Naval Architects, in 1860, describes the following experiment which he tried:—He took an ordinary ring life-buoy and on it he erected a tripod from which he suspended a plummet. When this was floated on waves he observed that the plumb line hung perpendicular to the wave slope under all conditions, even in the extreme case of a curling-over wave breaking on a beach. In short he found that a pendulum, floating on waves, departs as much from the vertical as the surface of the wave does from the horizontal, and cannot, therefore, be depended on, under those conditions, as an index of the true perpendicular.

It becomes interesting, therefore, to describe an apparatus made by Sir W. G. Armstrong, Mitchell & Co., the well-known English engineers, which has been experimented on by the British naval authorities and found to give absolutely perfect steadiness to search-lights and machine guns on a small, quickly-rolling and pitching vessel in a very rough sea. It has been, and is being, fitted to vessels belonging to the British and some other navies for mounting search light projectors. A search light projector throws a narrow ray of light, only about a degree wide, and in order that it may be of use for detecting the approach of torpedo boats or other objects at night, it must

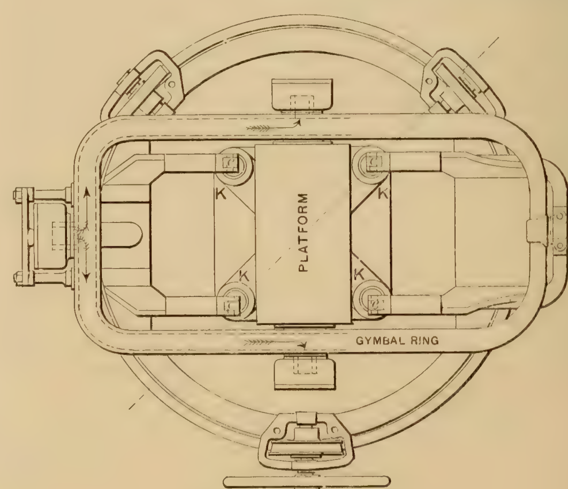


FIG. 2. PL .N.

be held so steady as to have no angular motion in a vertical plane comparable with the angle subtended by the ray of light, or it is impossible to keep the object in the field of illumination.

In this apparatus the platform (see Figs. 1, 2 and 3), or part to be kept steady, and to which the search light is attached, is hung in gimbals, so as to have angular freedom in every direction in the same manner as the bowl of a mariner's compass. The gimbals are supported on a turn-table which runs on wheels on the top edge of a tank or pedestal, so that the light may be trained to any point on the horizon. At each of the four corners of the platform is fixed a cylinder, *k*, having a ram or plunger, projecting upwards out of it, connected by a rod with a point, *e*, fixed, relatively, to the ship.

The ram, if forced out of its cylinder by water pressure, will cant the corner of the platform to which it belongs, downwards in the gimbals, so that by regulating the admission of water pressure to the four cylinders, the attitude of the platform in the gimbals can be controlled. This is done by the gyroscope *g*, Fig. 4, which is a heavy wheel, revolving in a horizontal plane on a ball and socket bearing, *b*, supported on the centre of a cross-shaped frame which connects the bottoms of the four cylinders. The bodies of these cylinders project downwards from the platform and are connected together by plates in such a way as to form a square cell within which the gyroscope revolves. The ball and socket bearing allows the gyroscope freedom to wobble or depart from the horizontal plane in every direction through an angle of about 3 degrees.

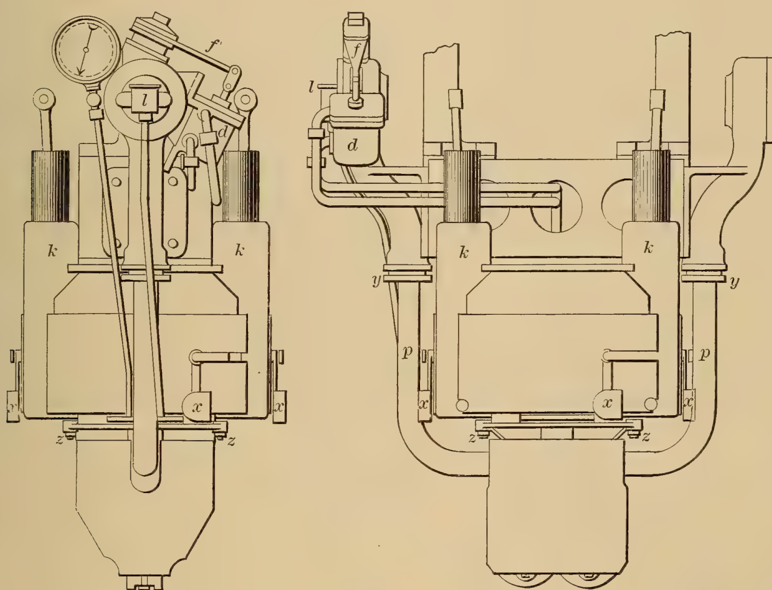


FIG. 3. DETAILS OF THE MECHANISM.

A supply of sea water, at the rate of 50 gallons a minute, and having a pressure of 100 lbs. per square inch, is pumped by a donkey engine to the platform, which it reaches by passing through the interior of the gimbal ring. This is made hollow for the purpose, and is provided with water-tight oscillating joints in its bearings. The water can thus pass without leakage through the moving parts of the gimbals to the platform, and is conducted by pipes *p* (Fig. 3) to the ball and socket bearing of the gyroscope, which

is made hollow so as to provide a passage for the water into a chamber *c*, in the interior of the gyroscope. From this chamber pass two radial passages, *r r* to the outside rim of the gyroscope, where they terminate in tangential jets, *t t*. These two jets are each 3-16 inch in diameter, and, by their reaction, cause the gyroscope to rotate at about

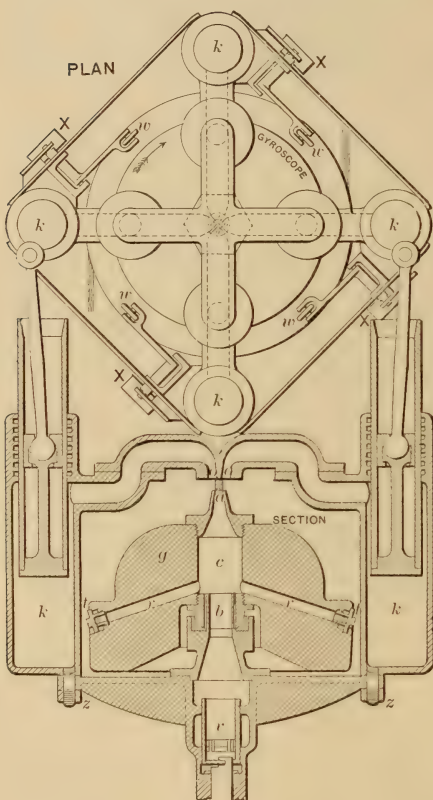


FIG. 4. THE GYROSCOPE.

1,500 revolutions per minute. About one-third of all the water escapes through these tangential jets, and is used in giving the gyroscope rotation. The remaining two-thirds pass upwards from the chamber, and issue from a jet *a*, ⅜ inch in diameter, which forms a prolongation of the upper axis of the gyroscope. It is this axial jet which provides the motive force for the controlling cylinders *k k* of the platform.

The centre of the ball and socket bearing is situated about the centre of gravity of the gyroscope, so that, without any extraneous force being brought to bear on it, the gyroscope might continue to revolve in any plane within the limits of wobbling freedom. In order to make the gyroscope seek to revolve in a horizontal plane, four small pendulums are hung outside it (see X Figs. 4 and 5). Each of these pendulums has a horizontal arm projecting from it, on the end of which there is a small wheel, W, which rests, and presses lightly, on the upper rim of the gyroscope. If the gyroscope is revolving in a horizontal plane, all these pendulums press on it equally with their horizontal arms, but should the gyroscope be out of the horizontal plane, then one pendulum presses more and one less hard, in such a way as to cause it to seek the horizontal plane. Of course, these pendulums are subject to the disturbing forces of the wave motion, as all pendulums are on board ship, and consequently do not tend to hang truly perpendicular to the horizon during the passage of a wave, but the gyroscope yields too slowly to the unequal pressure of the pendulums to take notice of these disturbances, which last only during the passage of a wave, and its position is that due to the mean of all the forces acting on the pendulums during a long period of time, which mean is the true perpendicular force of gravity. We thus have a gyroscope revolving in a horizontal plane and throwing a truly vertical jet out of the axial jet nozzle. The directing of this jet in the true vertical is the sole business of the gyroscope, and the only object of its existence.

Immediately above the axial jet, and about half an inch from it, are four open-mouthed ports *o o* (Figs. 4, 6, 7) formed in a circle, divided by radial divisions into four equal sectors. Their open mouths are directed downward towards the axial jet. The passages, of which they form the terminations, communicate each to one of the four cylinders. If the platform be truly horizontal, the axis of the axial jet passes through the centre of the circle

containing the four ports, and the jet is equally distributed between them ; but should the platform be the least bit out of the horizontal plane, some of the ports receive more of the jet than others, and this causes an inequality of pressure in the cylinders which cants the platform into the horizontal plane. Thus the vertical axial jet, playing on the four ports, acts as a force tending to keep the ports and itself concentric, and consequently the platform horizontal. The reason for using the jet as a connection between the gyroscope and platform is that it enables the gyroscope to powerfully control the platform, and yet suffer no reaction on itself. A very small force would be sufficient to disturb the gyroscope from its horizontal plane of rotation, but no force can be communicated to it from the platform, as it makes no difference to the gyroscope what the axial jet strikes against after it has left the nozzle. The water from the jets, after expending its energy in the manner described, falls past the gyroscope, through the open bottom of the cell, into the tank below, and thence, through a pipe, returns to the sea.

It will be observed that in the apparatus as above described, a disturbing force, acting on the platform, such, for instance, as a strong wind blowing

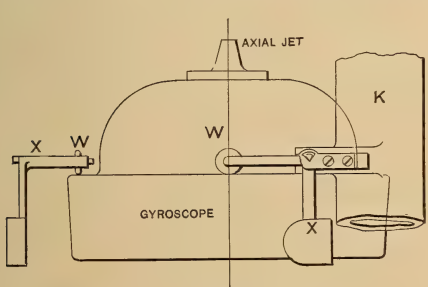


FIG. 5. A GYROSCOPE DETAIL.

against the projector, would actually cause a departure from the true horizontal, by the amount of the angle necessary to cause the jet to cover one port and uncover another sufficiently to establish the difference of pressure in the cylinders capable of withstanding the disturbing force. (See Fig. 6). The same kind of error also is caused by the angular speed of the ship's rolling, as then one pair of cylinders is filling with water and the other pair is emptying, and this also requires a de-

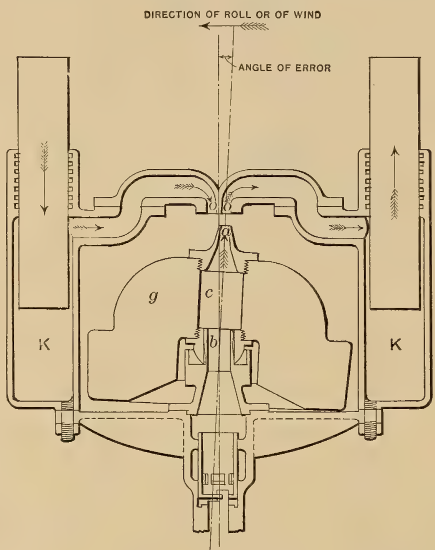


FIG. 6. DIAGRAM EXPLAINING THE ACTION OF THE GYROSCOPE.

parture from concentricity between the ports and jet. This error, due to either or both of the above causes, might, in extreme cases, amount to nearly two degrees, and it is to remove it that the correcting cylinder has been introduced.

The open-mouthed ports, against which the axial jet plays, have been described as formed by a circle, divided into four equal quadrants by four radial divisions at right angles one to another, each quadrant being a port. Two of these radial divisions lie in the vertical plane in which the search light is directed ; the others are at right angles to it. The former plane is the only one in which absolute accuracy is required. The radial divisions lying in it are made double, so as to include a narrow slit between the double partitions. This slit is divided in two at the centre (see ports, Fig. 7), so that, in addition to the four main ports, *o o o o*, we have

two small ports *s s* in the shape of narrow slits in two of the partitions. Under the elevating screw of the projector is a small cylinder *d*, called the correcting cylinder (Figs. 1, 3 and 7) having a piston and piston rod, to the end of which the elevating screw *n*, Fig. 1, is jointed. The piston is kept at midstroke in the cylinder by a stiff spring *f*.

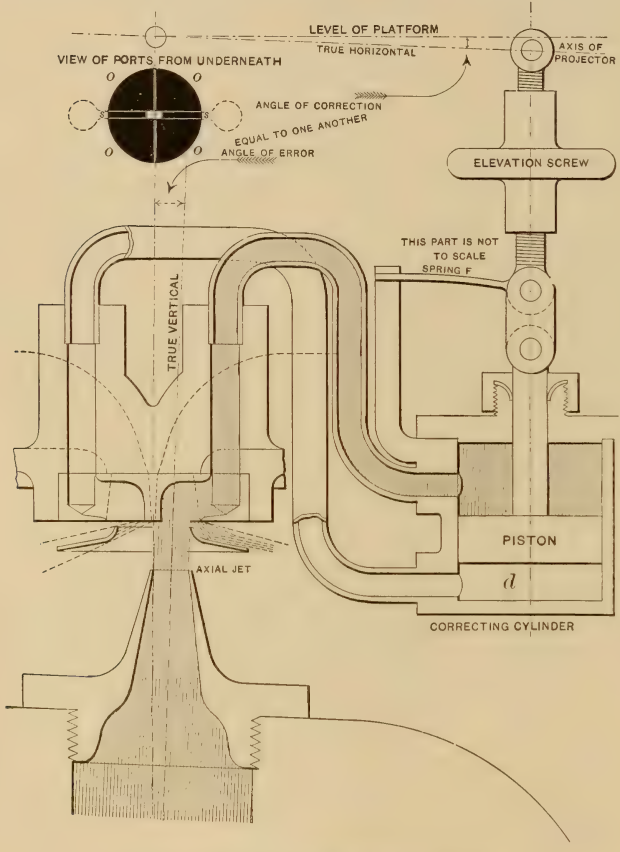


FIG. 7. ANOTHER GYROSCOPE DIAGRAM.

Each end of this cylinder is connected by a pipe to one of the narrow slit ports. Now, when, owing either to a disturbing force acting on the platform, or to speed of rolling, the above mentioned error occurs, the departure of the centre of the jet from the centre of the ports covers one and uncovers the other of the narrow slit ports *s s*, and thus causes a difference of pressure in them and in the two ends of the correcting cylinder, and a consequent departure from midstroke of its piston in proportion to the distance of the centre of the jet from the centre of the ports, which is the error (see Fig. 7). The strength of the spring is proportioned to the area of the piston, so that the travel of the piston gives angular motion to the projector in its bearings in the opposite direction, and to an amount equal to the error. The latter is thus exactly compensated for, and absolute steadiness is obtained under all conditions.

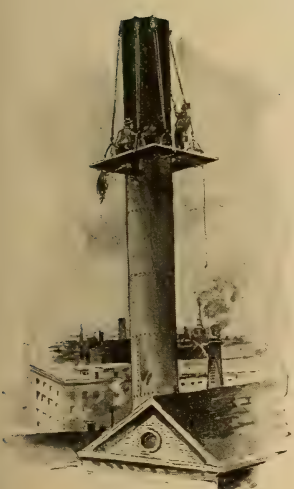
The first practical machine was fitted up on a steam yacht and subjected to a laborious course of experiment, of which the present perfection is the outcome. It was experimented with and reported on favourably by the captains of H. M. ships "Vernon" and "Excellent," the torpedo and gunnery schoolships at Portsmouth, as a means of mounting both search light projectors and machine guns and has, in consequence, been fitted to gunboats in the British Navy. Some of the other navies are following suit. There is no difficulty in mounting the smaller class of quick-firing guns, such as the 3 and 6 pounders, on a machine of this kind, specially designed for the purpose ; but for the larger guns an automatic firing apparatus has been contrived so as to fire the gun electrically at the instant in the roll when the ship's deck becomes horizontal.

But to return to the sea-sick passenger. On the machine which was mounted on the yacht a seat was provided on which a person could sit and

observe the steadiness by looking along sights at the horizon. The sensation of steadiness while seeing the ship rolling and pitching about under one was a curious one, and many people who tried it exclaimed that here at last was an alleviation, if not a perfect remedy, for sea sickness. It is true that the rising and falling motion is still there, but this can be to a great extent avoided by taking a position somewhere about midway between the bow and stern. But the angular motion of pitching and rolling is equally great in all parts of the ship and can be escaped only by some such contrivance as here described. A small cabin, kept steady by an apparatus of this kind, could easily be fitted on the English channel steamers, for seats in which many people would be glad to pay a high price on a rough day.

SOME AMERICAN VERTICAL BOILERS.

By Albert Spies.

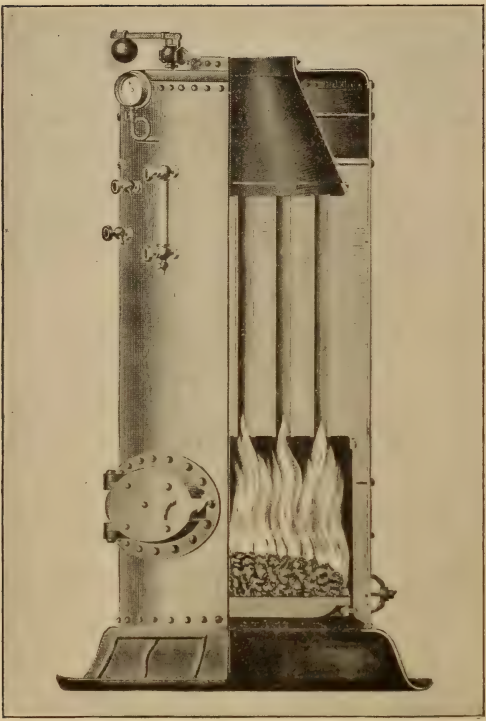


TAKE an ordinary horizontal tubular boiler,—one of the kind used in hot water heating plants, with the space inside the shell completely filled with tubes,—set it on end, with a furnace below and a chimney connection above, and you have pretty nearly what, for many years, has been the standard type of vertical boiler. And a good serviceable kind of boiler, too, it has been, with all its shortcomings. In cost it was moderate ; no special setting was required for it ; repairs were easily made ; and compactness and a reasonable degree of efficiency were secured with it, so that even to-day, it has not outlived its period of usefulness, but continues in favour, and is employed in a wide variety of cases where, all things considered, no other form of boiler will give the same degree of satisfaction.

And yet, for large powers, for high economy, for standard use in high-class power station work, even its distinctly good points could not command its application, except in forms so modified that in many cases little semblance remains to the early upright tubular boiler as we all know it. The designs have been carefully worked over, all with the end in view of turning out something better than the original, and the result is that while the later boilers also are vertical, in the sense, primarily, that they take up more head room than ground space, their tubes are not always vertical, nor even approximately vertical, and there is not in every case the conventional shell within which tubes and flues are disposed.

Nor are the tubes always fire-tubes, as in the ordinary vertical boiler, for conveying the products of combustion from the furnace to the chimney ; frequently in the newer and more complex designs, they are water tubes, instead, and do not always run in straight lines, but often curve and twist in vertical and horizontal planes, in helical paths, in almost all directions imaginable, with the one aim of making them efficient heaters of water, by promoting circulation and absorbing, to the greatest possible extent, the heat of the fuel liberated in the furnace.

One of the objections which has been urged against the plain vertical boiler, and not without some good reason, is

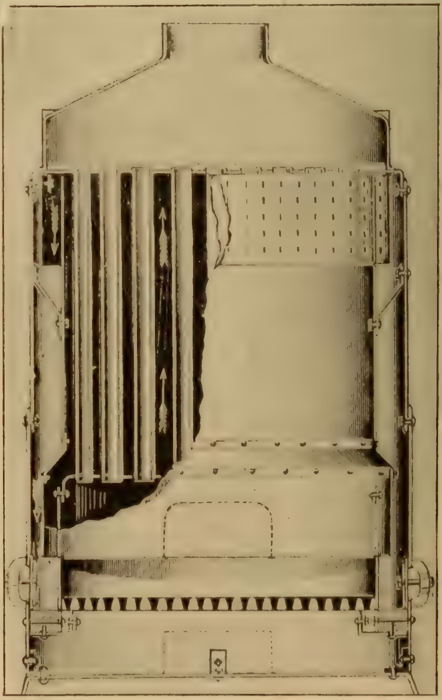


A SUBMERGED TUBE VERTICAL BOILER

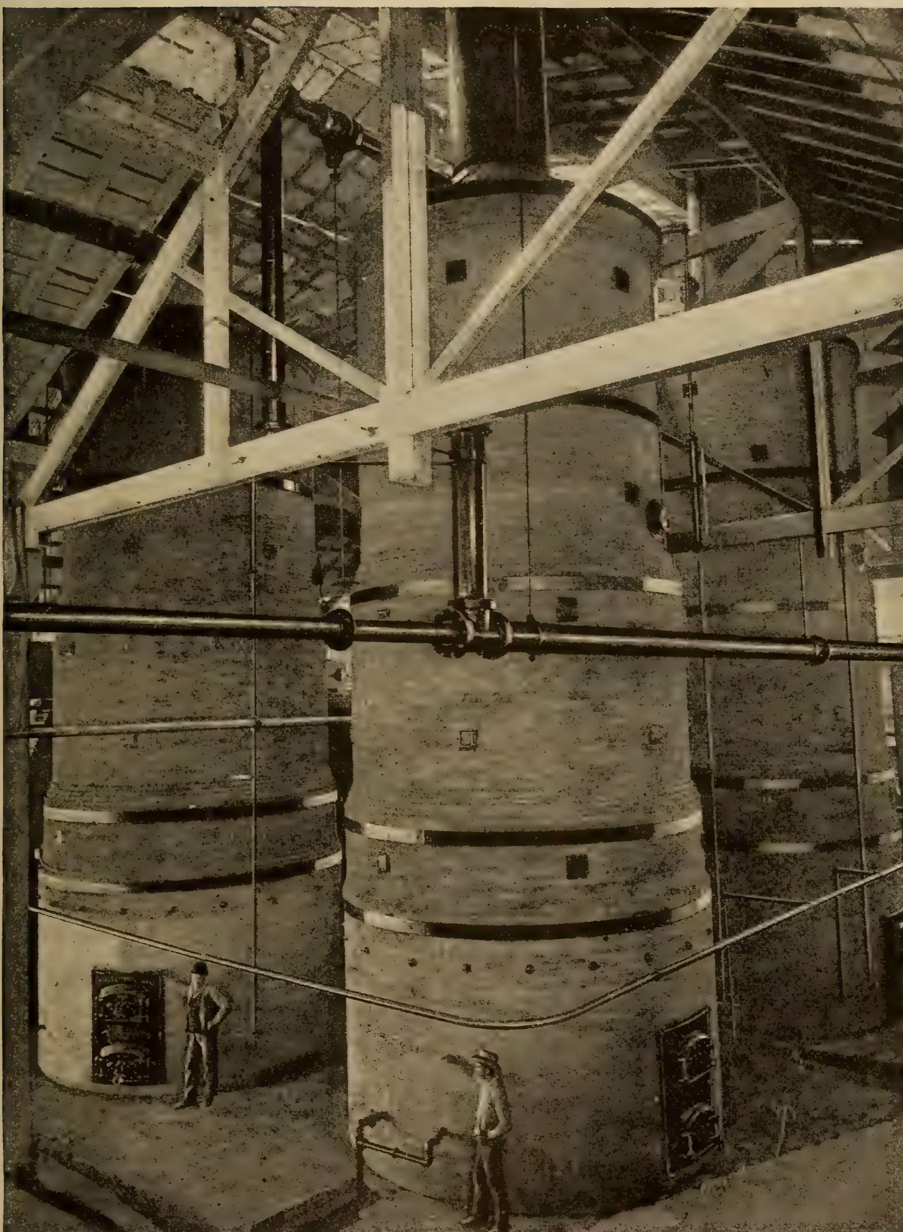
that since the upper ends of the tubes contain only steam,—the water line being some distance below,—they are apt to suffer from the comparatively high temperature of the gases passing through them, and burn out, particularly at the extreme ends, where they are expanded into the upper tube sheet. As a matter of fact, this is true to a considerable extent, and perhaps one of the first attempts to overcome this difficulty took shape in what is known as the submerged tube boiler of which an example is given on this page. In this the upper ends of the tubes terminated in a cone, below the water line, instead of extending clear to the upper head, and, accordingly, always have a protective layer of water over them.

The same object,—water protection of the upper tube ends,—is aimed at in the Payne boiler, though it is there accomplished in a different way. The water line is carried only part way up, as in the ordinary vertical design, but there is an arrangement of internal partitions, designed to effect the projection of water against the upper tube sheet by the ascending steam bubbles, and the tube ends are claimed to be thus protected against over heating. Examination of the cut of the boiler on the opposite page will, perhaps, make the nature of the arrangement clearer than it can be done in words. The partitions can be readily seen, and the one coming down from above is shown perforated so that the steam can escape and be taken off through the supply pipe to the engine. The water, coming down from the top of the boiler, follows the course of the arrows and passes down into the water leg into which the partition depends, and a pocket at that point serves to collect solid deposits which may afterwards be removed through the conveniently placed hand holes.

One of the earliest vertical boilers

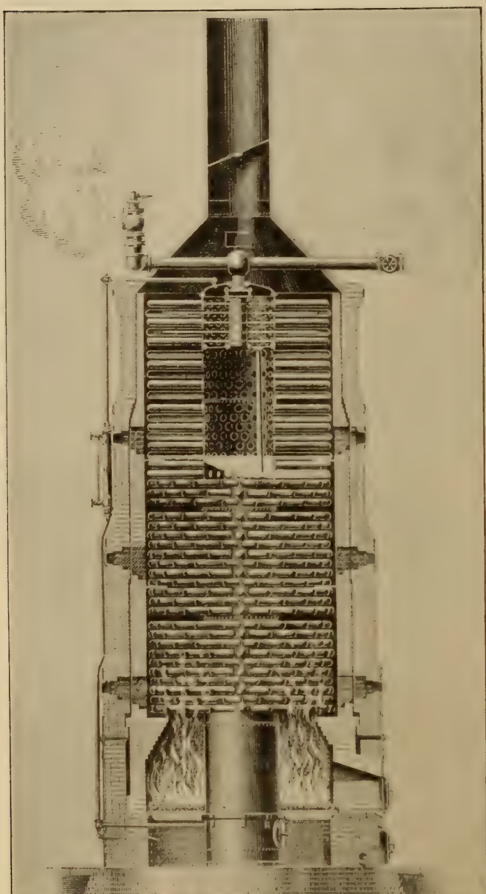


THE PAYNE BOILER, MADE BY MESSRS. B. W. PAYNE & SONS, ELMIRA, N. Y.



A HAZELTON BOILER PLANT IN CUBA.

in which the conventional vertical tube arrangement was abandoned, was the Hazelton boiler, or "porcupine" boiler as it has also been called, this name being suggested by the peculiar radial disposition of the tubes. The primary element in this boiler is a comparatively large standpipe, erected on an iron foundation plate of a diameter somewhat larger than that of the shell, with a manhole near the bottom, and the grates extending in a circle around it. Above the fire box and combustion chamber spaces, tubes radiate from the standpipe horizontally in all directions up to the top, and of lengths depending on the desired boiler capacity. Each



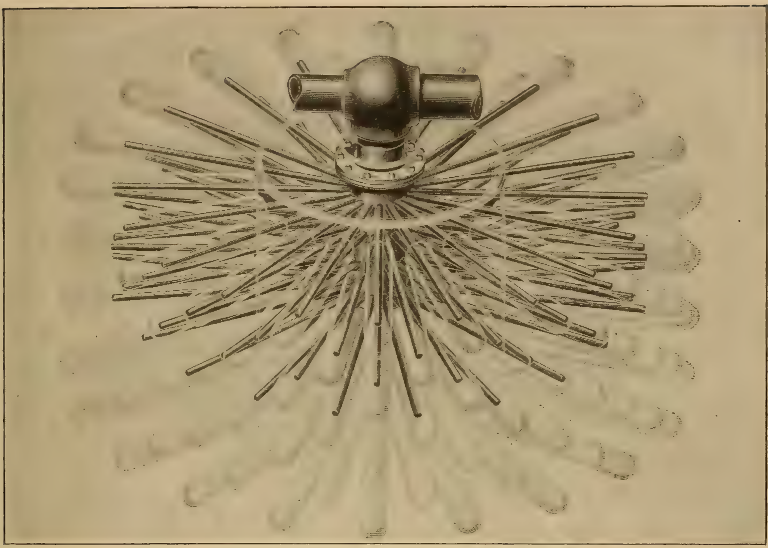
THE HAZELTON BOILER, MADE BY THE HAZELTON BOILER CO., NEW YORK.

of these tubes is closed at its outer end and is expanded into a bored hole in the standpipe.

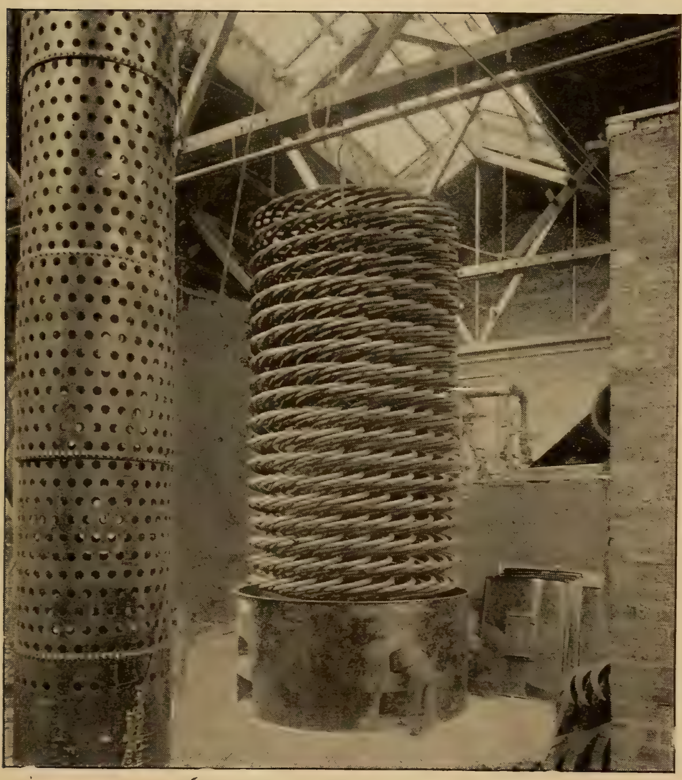
About three-quarters of the height of the standpipe, with its attached tubes, is occupied by water. The steam space above contains what the makers call a superheating device, and the steam goes into the main steam pipe through a number of small pipes which extend nearly to the outer ends of the steam tubes of the boiler. All the steam must go through these small pipes, thus insuring its dryness. As in other vertical boilers, there is in this one practically no low-water line, and as long as there is water above the grates, there will be steam in the shell and tubes. The feed water enters at a point below the grates, and passes up through the fire-box portion of the standpipe nearly to the water line.

The heat from the grates is concentrated around the standpipe, below the tubes, by the inverted-funnel shape of the brickwork line of the furnace. The tubes are not placed in vertical rows, but are "staggered," and as the heat passes upward around the sides of the first series of tubes, it strikes squarely against the bottom of the next above, and so on to the top, taking a spiral course in its passage from bottom to top of boiler. Of course, the tubes separate as they extend out from the standpipe, and at the outer ends the heated gases could go up freely, were this not prevented by horizontal circular deflecting plates put in at intervals above the brickwork. Access to the interior of the boiler can be readily gained through the already mentioned manhole in the standpipe, below the grates, and, going up, every tube can be reached. For the utilisation of waste heat particularly, these boilers have given very good results.

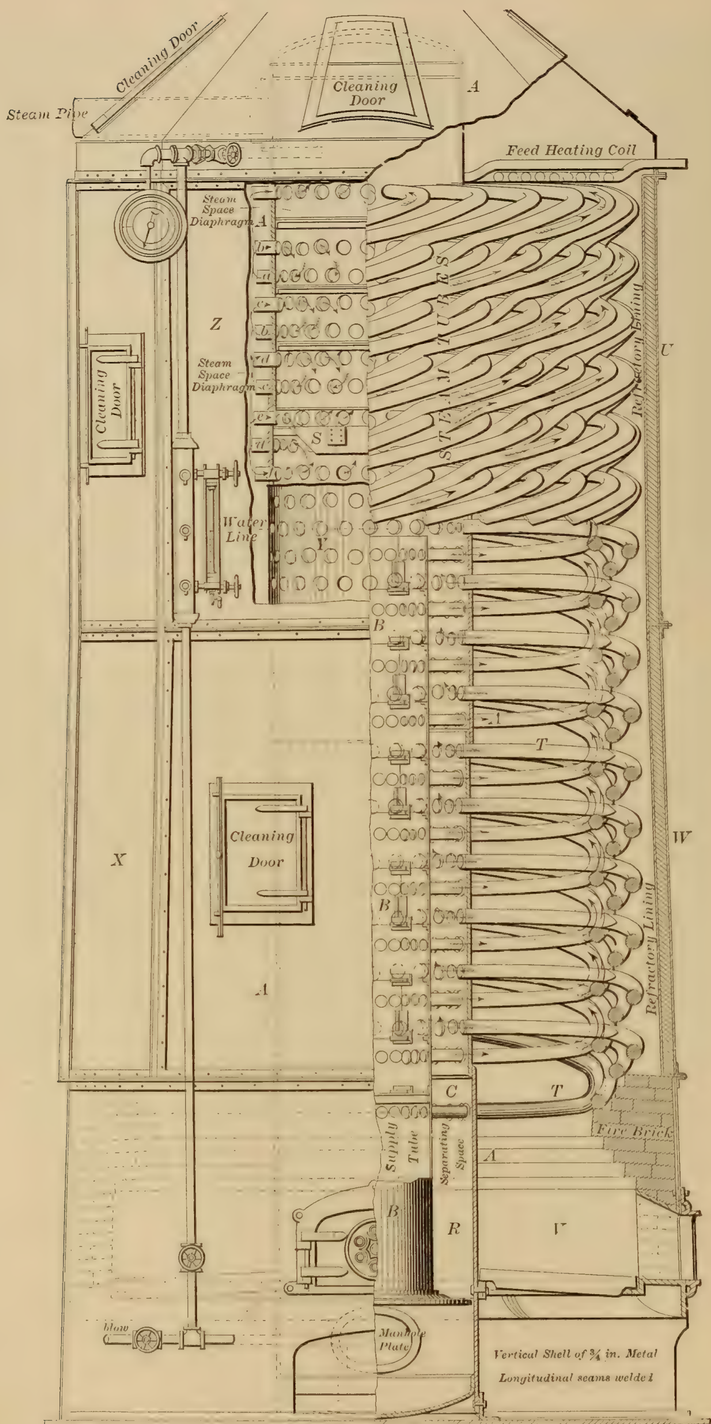
Among the vertical boilers which have, in a general way, become known as "pipe" or "coil" boilers, the Morrin, or Climax, has, in recent years, met with considerable favour. In this



THE "STEAM TAKE-OFF" IN THE HAZELTON BOILER.



THE CLIMAX BOILER, MADE BY THE CLONBROCK STEAM BOILER WORKS, BROOKLYN, N. Y

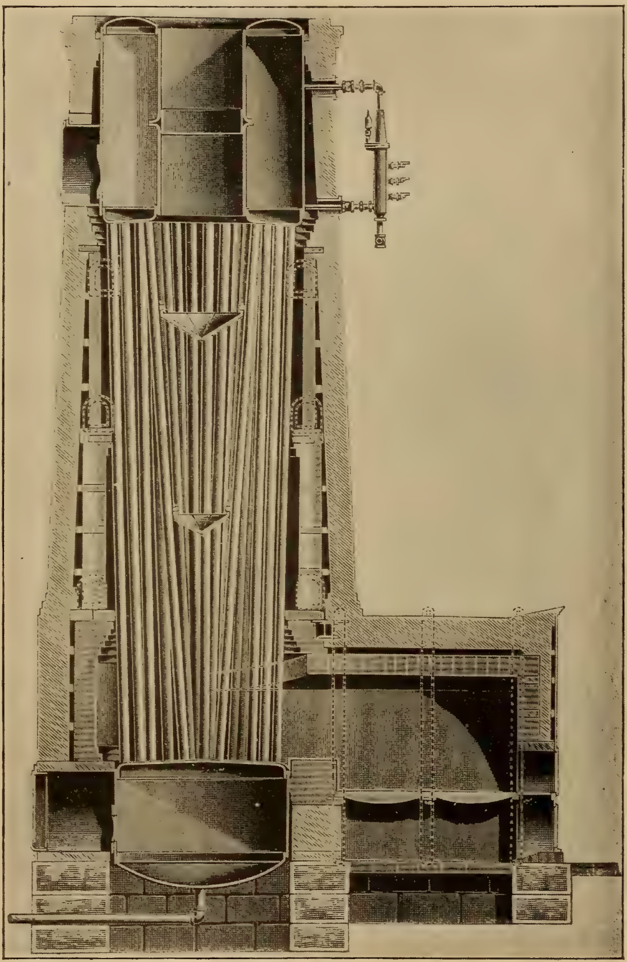


ELEVATION AND SECTION OF THE CLIMAX BOILER.

boiler, too, there is a central standpipe into which tubes are expanded, but these are not short and straight and disposed radially, but are arranged in the form of loops, as the illustrations on pages 161 and 162 clearly show. The first of these represents one of the large central tubes, or standpipes, without the smaller tubes, showing simply the holes drilled for their insertion, and also a boiler with the outside casing removed. The other illustration represents an elevation and a vertical section through the boiler. While at a first glance the latter appears complicated, closer examination shows it to be really quite simple.

The vertical central cylinder *A* extends through the whole height of the generator, and its construction is similar to that of any ordinary cylindrical boiler shell; that is to say, it is made perfectly steam-tight, also strong enough to resist the internal pressure, and is provided on top with the usual manhole plate. The loop-like tubes *T* are expanded into the shell of the cylinder *A*, and the extremities of each are in different planes, as may be seen by referring to the lower, shaded tube in the vertical section.

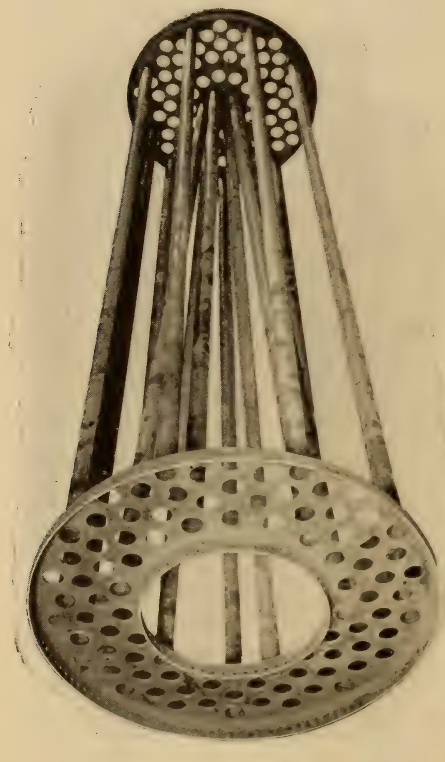
Within the cylinder *A* is another cylinder *B*, open at both ends. The bottom of this rests on brackets riveted to the outer cylinder, and the upper end of cylinder *B* extends about up to the water line. The cylinder *B* is, in fact, a built-up one, being made in short sections, so that they can be readily removed when repairs are necessary. Since the pressure inside of the cylinder *B* is equal to the pressure outside of it, comparatively light iron is used in its construction. The joints of the sections need not be steam-tight, and consequently they are held together simply by means of a few bolts. It will be seen that the lower ends of the tubes *T* are connected to the inner cylinder *B* by short tubes *C*, crossing the annular space *R*. These short tubes are simply driven into the tubes *T*; their other ends rest in the holes



THE CAHALL BOILER, MADE BY MESSRS. H. E. COLLINS & CO., PITTSBURGH, PA.

through the cylinder *B*. The ends of the short tubes need not be, and are not expanded, as perfect steam-tight joints are not necessary.

The fire-box surrounds the cylinder *A*, and is annular in form. The casing *U W* is made in sections, bolted together. This arrangement allows any one of the sections, such as *X*, for instance, to be removed without disturbing the other sections, when it is necessary to replace a tube. Sometimes the inside of the casing is lined with terra-cotta, and in such cases the inner plates for the refractory lining, shown in the illustration, are not used.



UPPER AND LOWER TUBE SHEETS OF THE CAHALL BOILER, WITH A FEW CONNECTING TUBES IN PLACE.

The water, as it is heated, ascends in the loop-like tubes *T*, flows into the annular space *R*, and a fresh supply of water is drawn from the inner cylinder *B*. In this manner a constant circulation is maintained in the tubes *T*, causing the steam and water in the annular space *R* to ascend and the solid water in cylinder *B* to descend. The deflector *S*, directly above cylinder *B* tends to separate any water that may be carried by the steam. The tubes above the water line will dry and superheat the steam and the diaphragm plates above the deflector compel the steam to circulate, in succession, through each tier of the steam and drying tubes. The feed water in entering the generator has to flow through the coil resting on the upper tier of tubes, and is well heated before it mingles with the water in the generator.

Since the largest diameter exposed to bursting pressure is the comparatively small vertical cylindrical shell, it will be seen that these generators can be made of large power and still be safe under any pressure desired. When worked under ordinary pressures the factor of safety is high.

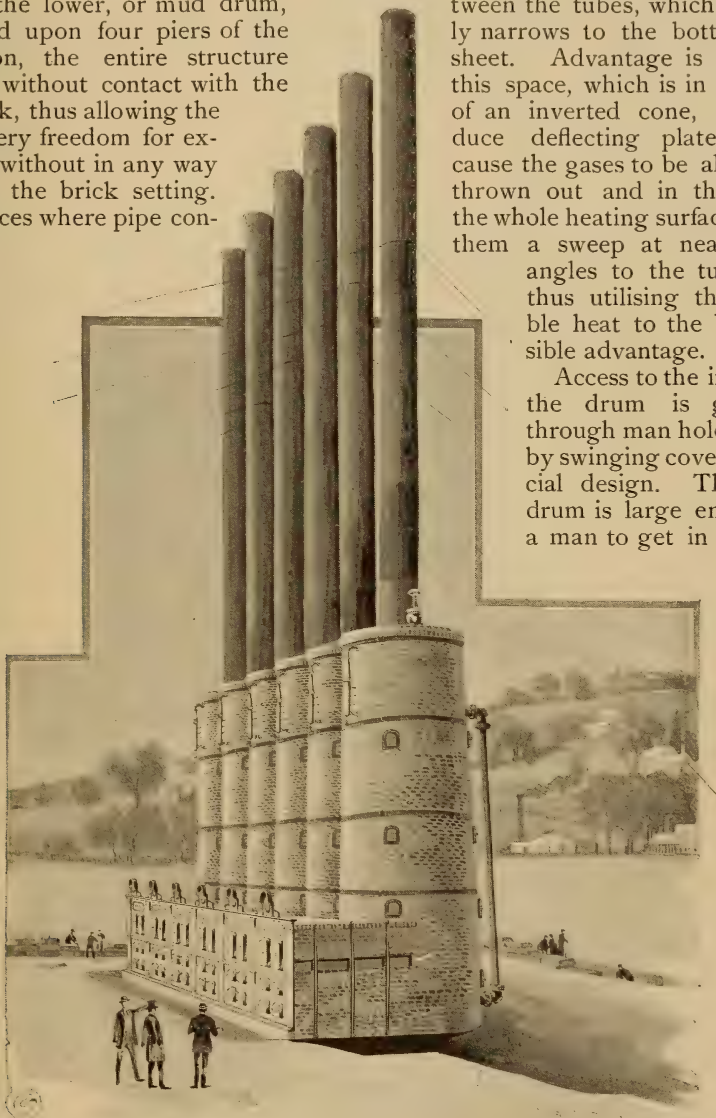
The Cahall boiler, one of the straight-tube variety, brought out only a few years ago, consists, essentially, of two drums, arranged one above the other, and connected by 4-inch tubes in the manner very clearly shown in the illustration on page 163. The upper or steam drum has an opening through its centre for the exit of the hot gases. These, although reduced to a very low temperature in passing through the closely grouped tubes of the boiler, will impart most of their retained surplus heat to the metal sides of the passage through this upper drum, thereby tending to slightly super-heat the steam in the chamber above. The water line in the upper drum is about a foot above the bottom of the drum, the latter itself being about six feet high in the clear inside, leaving a space of five feet between the surface of the water and the point at which the steam is drawn off from the boilers, thus tending to prevent the carrying over of water in the steam.

An external circulating pipe, not shown in the illustration, comes out from the upper drum, just below the water level, and is carried downward,

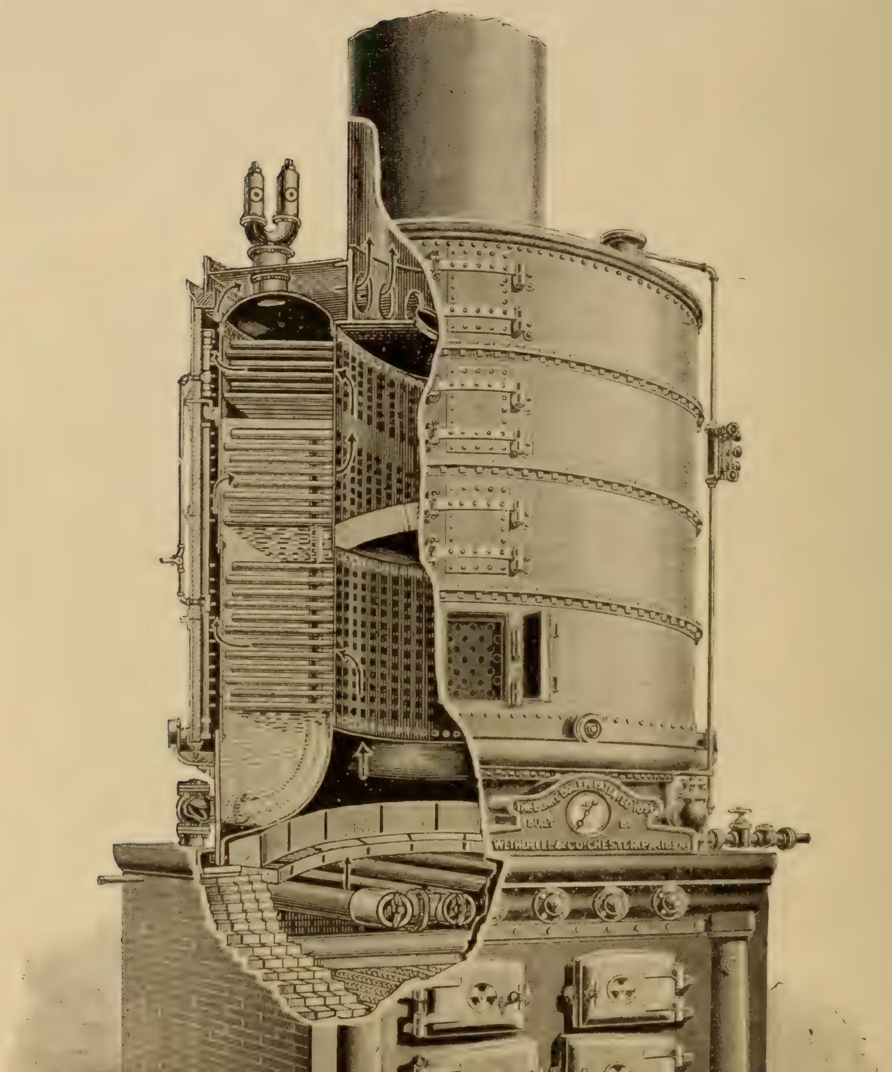
outside the brickwork, to a point just below the tube sheet of the lower drum, where it enters that drum. The boiler rests upon four iron brackets riveted to the lower, or mud drum, supported upon four piers of the foundation, the entire structure standing without contact with the brickwork, thus allowing the boiler every freedom for expansion, without in any way straining the brick setting. In all places where pipe connections are made to the boilers through the walls, they are encased in expansion boxes.

Owing to the fact that the hot gases escape through the central opening in the upper drum, the upper tube sheet has a circular opening in its centre, leaving a central open space between the tubes, which gradually narrows to the bottom tube sheet. Advantage is taken of this space, which is in the form of an inverted cone, to introduce deflecting plates, which cause the gases to be alternately thrown out and in throughout the whole heating surface, giving them a sweep at nearly right angles to the tubes, and thus utilising the available heat to the best possible advantage.

Access to the interior of the drum is gained through man holes, closed by swinging covers of special design. The upper drum is large enough for a man to get in and walk around, so that the tubes may be easily examined and scale removed if necessary. The scraper used for cleaning the tubes is made in sec-



A BATTERY OF CAHALL BOILERS.



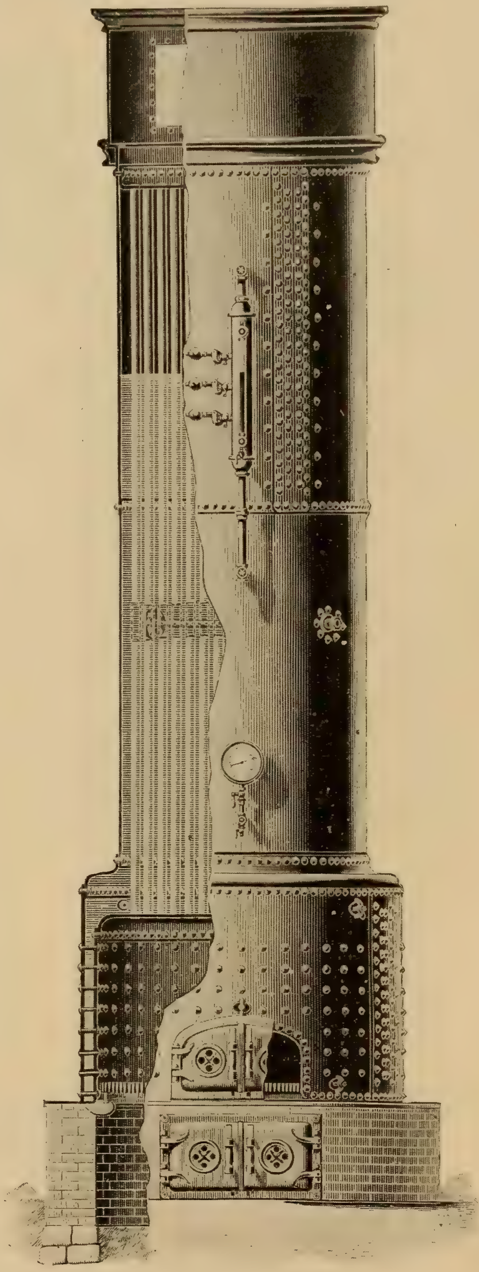
THE BERRY BOILER, MADE BY MESSRS. ROBT. WETHERILL & CO., CHESTER, PA.

tions a trifle less than six feet long. Four of these sections are used, and the man who is cleaning the boiler takes them into the upper drum and pushes the first section down as far as it will go, then simply hooks the second section to that, and continues doing this until the scraper has gone entirely through the tube, forcing any scale that may have been deposited on the sides of the tube straight through to the bottom drum.

Ample provision also is made for removing defective tubes from the boiler. To this end the top part of the upper drum has six hand holes, besides two others for steam pipe and pop valve connections. By means of these eight openings, any of the tubes needing removal, after having been cut loose from the tube sheets, can be pushed up through the tube hole from which it has just been cut and through the most convenient of these openings in the top head. The new tube, to replace the defective one, is just as readily passed into the boiler through the same openings.

The Manning boiler which is now made by a number of well-known American firms, was one of the first large vertical boilers to be brought into prominence, and in the last half-dozen years or so has acquitted itself well in general service. In the old vertical boiler it was often well-nigh impossible to thoroughly clean the crown sheet and the water leg, for the simple reason that they were inaccessible. In the Manning boiler, however, the outer fire-box shell is carried well up above the head, and hand holes are placed exactly on a line with the crown sheet. The tubes are placed in straight rows, and at right angles to one another extend two cleaning channels of ample size. A bent tube may therefore be inserted, and every part of the crown sheet thoroughly washed and cleaned without the least inconvenience. In the water leg also are placed a number of hand holes and a cleaning chain by means of which any sediment that may accumulate may be stirred up and removed.

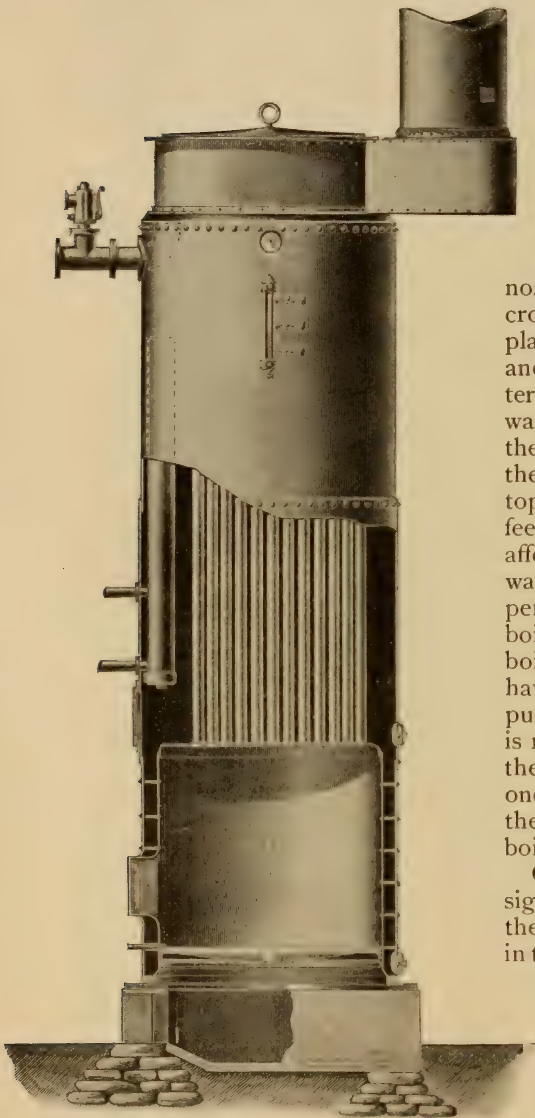
The boiler, being internally fired, has no brick work whatsoever, except the foundation upon which it rests, and this does not come in con-



THE MANNING BOILER.

tact with the fire at all. It is subject to no usage involving more wear and tear

than the brick walls of the factory itself. This is an advantage sometimes well worth bearing in mind. The outer shell plates which must bear the greatest strain



THE REYNOLDS BOILER, MADE BY THE EDW. P. ALLIS CO., MILWAUKEE, WIS.

and which it is impossible to brace or strengthen by stay bolts, receive no heat from the fire and can therefore be made of any required thickness. The fire-box sheets, on the other hand, can be properly stayed in the usual way and may, therefore, be made thin enough to prevent burning.

In the Reynolds boiler, of which one form is shown on this page, the tubes are set in rows, radiating from a large man-hole located over the fire door and bottom tube sheet, so that every flue and all parts of both tube sheets can be inspected and cleaned when the man-hole cover is removed. Hand-holes are located opposite the man-hole for admitting light for inspecting and inserting a hose nozzle for washing the tubes and crown sheet. Hand-holes, too, are placed at intervals around the base and through these sediment in the water legs may be removed. The feed water is pumped into a reservoir inside the boiler, closed at the bottom, so that the discharge into the boiler is over the top, and as it is so much larger than the feed-pipe, the upward flow is very slow, affording ample time for the entering water to become heated up to the temperature of the water already in the boiler. The smoke hood on top of the boiler is furnished with a revolving top having a removable cover. For the purpose of cleaning the flues this cover is removed and only a small portion of the total number of flues are exposed at one time. This arrangement enables the fireman to clean the flues while the boilers are in operation.

One of the most recent of vertical designs is found in the Berry boiler, of which the main features are very well shown in the illustration given on page 166. It is made up of two cylindrical shells, united in the manner shown, with tubes passing through the intervening spaces. The products of combustion rise into the internal combustion chamber, are deflected by a fire brick arch above, and pass through the tubes to the outside flue, then upward and inward through the middle section of tubes to the central flue, then upward and outward through the third section of tubes to the outer flue, then upward and inward over the top of the boiler

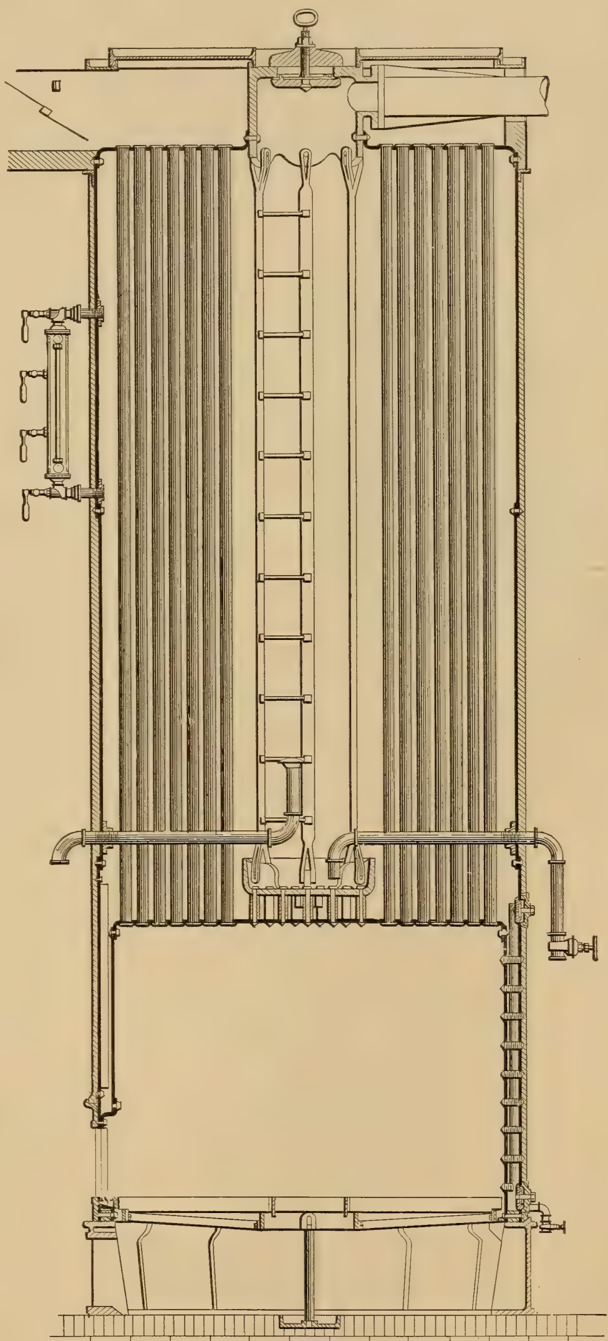
to the stack. The third section of tubes is in great part located in the steam space and serves to moderately superheat the steam.

The outer casing of the boiler is lined with non-conducting material and is mounted upon wheels which run upon a track secured to the boiler. The top and bottom and middle joints are made with loose sand so that the casing may be easily revolved. A rack and pinion is provided for this purpose. Doors are provided from top to bottom, which, by revolving the casing, may be brought opposite any part of the boiler for inspection, cleaning or repairs.

Secured to the inside of the casing is a blast pipe having a nozzle opposite each tube in a vertical row. By means of a flexible pipe a steam connection is made and by revolving the casing, all the tubes may be blown clean while the boiler is in full service. It is stated that but a few minutes are required to blow the tubes of a 250 h. p. boiler clean without discomfort to the operator.

Still another form of generator,—again of the straight-tube variety,—is the Corliss boiler, shown on this page, the illustration being a vertical section which requires little explanation. The tubes are disposed in annular form, leaving an open, central space from the top of which the steam supply is taken off, and through which easy access may be had to the interior. For this purpose a hand-hole is arranged as shown.

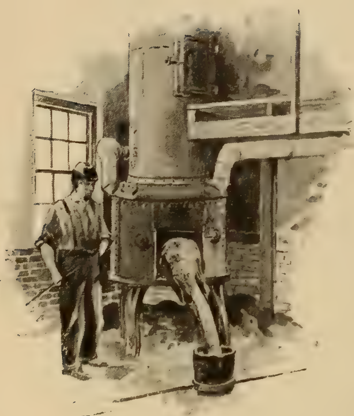
The list of vertical boilers is, of course, by no means exhausted by those here shown. Hosts of designs have been planned and put on the market, and from these the present selections have been made, simply as examples of current practice, all of them having attained more or less prominence in regular work.



THE CORLISS BOILER, MADE BY THE CORLISS STEAM ENGINE CO., PROVIDENCE, R. I.

FALSE ECONOMY IN FOUNDRY EQUIPMENT.*

By H. Hansen.



ANY one acquainted with the foundry business knows that at the present time the operation of a foundry compels the injection of several grains of economy at different places in order that there may be something felt on the right side of the ledger.

The term economy poorly fits too many of the savings made in the foundry. Not everything that makes a saving possible is economy ; some attempts at saving might better be labeled extravagance. That the foundry industry has been prolific in examples of bad judgment and of calculations that failed to materialize is shown in the many wrecks by the wayside and in dividends that were far smaller than anticipated. The best is the cheapest, though some founders apparently act on the principle that the cheapest is the best. To such it seems economical to employ any article or tool that answers the purpose.

Shops producing their own tools exclusively are becoming scarce. Home-made contrivances are giving place to machinery perfected by specialists and installed on the purely business principle that they will lower the cost of the product. Making a special study of the needs of each industry has not only furnished better tools but decreased their cost in corresponding proportion. The machine shop that would undertake to build a lathe or boring mill for itself would find itself greatly handicapped in the matter of cost, when compared with one of the regular tool works. But even leaving the question of first cost aside, how would the home product compare with that of a firm making a business of building such tools ? Would it give the same degree of efficiency with the same expenditure of power ?

Power costs money. Any tool that requires a greater amount of power than others of the same class and efficiency is not economical. Yet how many foundries disregard this altogether, and purchase tools that are sometimes called regular steam-eaters, because they are cheap, and then pay the difference many times over in extra cost of operation.

The manufacture of foundry tools is becoming a trade of itself, and the men engaged in it are bending every energy toward developing superior appliances for the foundry. The ordinary chaplets, for which almost every foundry used to rely on the blacksmith nearest at hand, and which have probably been the cause of more castings being discarded and patched up than any other thing of their size, are being made by special methods and presented in a far superior condition, besides being placed on the market at a price which would not keep a blacksmith in tobacco. At the same time there are many foundries that still insist on making their own inferior chaplets. Are they practicing economy ?

Not long ago I was employed by a firm who concluded to make a grinder themselves, rather than purchase one. They had the draughtsmen, pattern-

* From a paper read before the Western Foundrymen's Association.

makers, machinists and moulders, with plenty of wood and pig iron in the background, so it entered their mind that there could not be much expense attached to converting this into whatever they saw fit. Owing to the ignorance of their foundry foreman, who was not accustomed to this class of work, the main casting or bed was cast three times before producing a passable piece of work. The smaller parts went the same way, and there was hardly a piece connected with it that was made on the first trial. In nearly every case success came only after some experience had been paid for. When it came to assembling, I have a distinct recollection of several pieces refusing to be put together. Parts which should have been cast separately were consolidated to make it easier for the pattern-maker and machinist, with the result that lugs and projections protruded in such a manner as to resist all attempts at bringing them together. When I last saw these relics of an ill-fated enterprise, they were covered with dust ; and although times were dull and several shut downs became necessary, this firm who were going to make this machine so cheap, never said a word about finishing it up and getting it ready to work.

The proprietors of a neighbouring foundry about the same time found themselves in want of a crane to replace an old rattle-trap that threatened to fall down and carry with it more destruction than it was worth. Inquiring of several dealers in foundry equipments, they were surprised to learn that a crane would cost more than the charge for freightage. But they found a way to overcome this difficulty. They had a machine shop and foundry, they had all kinds of materials that are supposed to enter into the composition of a crane. They had men, too, who knew how to use up such material, so why should they not make the crane at home and get just what they wanted? But as the making of cranes was not their business, a well paid employee was entrusted with the gathering of information on this subject. After a month spent in visiting places where cranes were in use, measuring their dimensions, finding out the ratio of their gearing, the size of chain used, etc., they were ready to make what patterns were necessary and borrow and make answer whatever shortshifts they could make up.

Perhaps you think they didn't make that crane work ; but they did. And I understand the intention was to cast a fancy name-plate to adorn it, but this motion was reconsidered when they discovered the amount of power they had to furnish this creation of theirs before it would budge. Power is money, and if this foundry practiced economy in building a crane, say, 25 per cent. less than they could purchase one, when it required 75 per cent. more power to operate it, I want you to tell me where it is.

It takes a man with good abilities to become a good imitator as it does to be a fair originator. In fact, it takes a very smart man and mechanic to execute a first-class job of imitation. It seems the easiest thing in the world to take a machine to pieces, secure its measurements and turn out duplicates. Yet how many of such imitations have the efficiency of the original, when assembled and put through the real test of actual work?

As amateur tool builders, most foundries do not achieve success. They may for a while be deceived by the external appearance of things, yet we all know how soon a dollar's worth of extra labour can be consumed on a crane or other tool without exciting suspicion. Such leaks are common, and increase the cost of every pound of castings made, but it is seldom that a determined effort is made to locate them. There might be some unsavoury disclosures that would endanger the position of many a designer, attempting to administer to the wants of people with whose requirements he was entirely unfamiliar.

The admiration we show for the work accomplished by a tool is doubly increased if it requires only a minimum of power in its operation. Although

none of us entertain the idea that work can be performed without the consumption of power, yet we have a high regard for those tools that get along with the least. We all recognize the advantage these have over others that call for a larger expenditure.

It is false economy that suggests to many of our foundrymen to-day that labour-saving tools can be made home and reach the same degree of perfection attained by builders who devote their whole time to tool-building exclusively. Without reserve, not one foundry in ten can produce a creditable tool, simply because such an attempt involves entering strange fields where experience must largely be paid for in failures.

IRVING MURRAY SCOTT.

General Manager of the Union Iron Works, San Francisco.

By P. M. Randall.

AMONG the men whose names have become closely connected with the revival of ship building in America, and especially with the development of iron and steel vessel construction, Mr. Irving Murray Scott occupies a leading position.

His father was a farmer and a prominent member of the Society of Friends, —a man of fine mind and strong character,—and the son inherited many of his sterling qualities. His boyhood was passed on his father's farm, and even at an early age he evinced marked mechanical ability. He was educated in the public schools, and afterwards at the Milton, Maryland, Academy, where he studied for three years. Upon leaving school his father offered to defray the expense of his preparation for one of the learned professions, but he preferred to enter the field of mechanics and was accordingly apprenticed to the machinist's trade in Baltimore. During his period of service as an apprentice he thoroughly mastered his trade and also became an expert draughtsman. Afterwards he worked for some time in Baltimore, being mainly employed in supervising the construction of steam engines, and giving his leisure hours to study. Three nights a week he spent at the Mechanics' Institute, the fourth night in the study of German, and the fifth, at lectures.

In 1860 Mr. Scott was engaged as draughtsman by the Union Iron Works, at San Francisco. In this new field of labour his advance was rapid and he was soon made superintendent of the works. In 1865 he became a member of the firm and its general manager and superintendent, which position he still retains. When he first became associated with the works, only 22 men were employed, while to-day they furnish employment to 1400 men and represent an invested capital of $2,000,000. They were, for many years, chiefly engaged in the construction of mining machinery, and in this department of mechanics they long held the first place on the Pacific Coast of the United States.

In 1880 Mr. Scott went on a trip around the world with James G. Fair, and, while in Europe, made a close study of the industries and industrial establishments of the several countries which he visited, giving special attention to the ship-building plants of France and England. Upon his return home the Union Iron Works were enlarged and greatly improved, so that now they cover 25 acres on the water front of San Francisco and are the most complete of their class in the United States.

The firm was made into a corporation in 1882, and in 1884, at the instance of Mr. Scott, engaged in ship building. Since that time the company has built for the United States Government, the "Charleston" and "San Francisco," unarmored cruisers of 4130 and 3750 tons, respectively, and the "Monterey," a powerful coast defence vessel. It has also built the cruiser "Olympia," of 5870 tons burden, and the battle-ship "Oregon," of 10,200 tons. The company has further built many vessels for private owners.

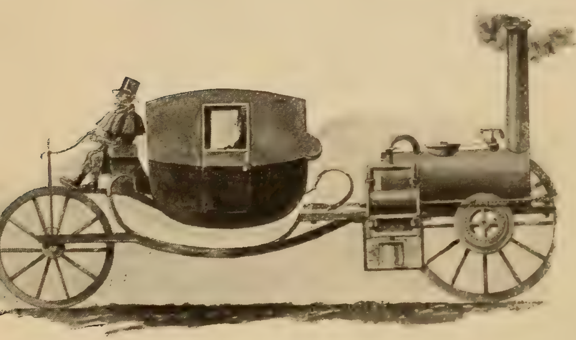
Mr. Scott, besides devoting his ability and energy to building up the Union Iron Works to their present proportions, has engaged successfully in mining and banking and is a trustee or director in many institutions. To him was largely due the development of the Clipper Gap Iron Company, probably the richest in California. As president of the Art Association at San Francisco, of the Mechanics' Institute, as regent of the University of California, as trustee of the Leland Stanford, Jr., University, and of the Free Library, his influence has made itself felt. He was one of the three men appointed to receive the Japanese Embassy in 1879, and was appointed also to extend the welcome of the citizens of San Francisco to General Grant on his world-embracing tour. In April, 1891, he was made president of the California Commission to the World's Fair.

He is a wide and constant reader and an acute and original thinker, and his contributions to the magazines and reviews upon the labour and other industrial problems have, at different times, attracted much attention. Since 1890 he has strenuously advocated the erection on the Pacific Coast of a government plant for the construction of heavy ordnance and the adoption of a more complete and effective system of harbour defence.

Current Topics.

With the growing use of electric power for street car propulsion, the "passing of the horse" has become a favourite theme for newspaper discussion, and just now it is likely to receive still further interest from the work that is being done in the way of perfecting the various types of self-propelling road vehicles. Horseless carriages, indeed, there are galore, some propelled by means of electric motors worked from storage batteries, others by oil engines,

and others again by steam engines. while compressed air and carbonic acid gas motors are not likely to lack representation in this new field. It needs only a little investigation to bring to light dozens of such vehicles, modeled with the view of satisfying all the re-



SYMINGTON'S STEAM COACH OF 1786.

quirements which wagons drawn by horses are expected to meet, and in some respects they have been much more successful than is popularly supposed. The famous Paris horseless vehicle contest early in this year, and the recently proposed trials at Chicago gave striking proof of this. In a number of the big cities the novelty of seeing horseless carriages in the streets is, in fact, already beginning to wear off. It is all the more interesting, therefore, to bring to light a few examples of comparatively early achievement in this line, among them the road locomotive designed as long ago as 1786 by William Symington, one of the earliest pioneers in steam engineering.

SYMINGTON'S outfit, already mentioned in an earlier number of this magazine, consisted of a carriage with a locomotive behind, mounted on four wheels. A cylindrical boiler was used for raising steam which was supplied to two horizontal cylinders, one on each side of the firebox. The motion of the pistons was transmitted to the driving wheels through rack rods which worked toothed wheels placed on the hind axle on both sides of the engine, and Symington stated at that time that one advantage of this method of applying the power of the engine was that it always acted at right angles to the axle of the carriage. Considering the early date of the invention, the arrangement showed much ingenuity, though it was allowed to sink into forgetfulness, never to have an awakening, while the inventor turned his thoughts to other projects. Nearly half a century later—in 1827—another steam carriage made its appearance in England and, for a time, created not a little commotion. It was the invention of a Mr. Gurney and was probably well illustrated in the little sketch here shown, which was redrawn from an engraving in the London *Engineer* of recent date. Originally it appeared in the London *Observer* of December 9, 1827. Gurney's boiler was of the tubular type, for which a great claim of safety from disastrous explosion was made even at that time, and the engine appears to have been made up of several cylinders, transmitting power to the hind axle. There were, besides, "propellers," described as moving like the hind legs of a horse, catching the ground and then forcing the machine forward. In this respect it probably resembled somewhat the "horse-leg locomotive," built in 1813 by a Wm. Brunton, which pushed itself along by means of its hind legs

GURNEY'S STEAM CARRIAGE, 1827

after the manner of a grasshopper, or of a boy sitting on the tailboard of a toy cart. Like the Symington carriage, however, Gurney's invention was short-lived, and nothing more seems to have been heard of it after its brief

newspaper career. As forerunners, however, of the horseless carriages of to-day which promise to enjoy a more material existence, they are interesting and instructive.

LIGHT iron castings are, at the present day, made in much larger quantities than any one who has never investigated the subject would imagine. Many years ago articles cast of iron, and of a fragile and ornamental character, known as "Berlin jewelry," were in extensive use and it was then thought almost impossible that these should be simple iron castings. At present, however, even more intricate articles are cast of iron, but instead of being simply of an ornamental character, they serve a variety of directly useful purposes, comprising, as they do, scissors and shear blanks, clock bells, clock and door keys, harness buckles, and a multitude of others, not one of which will weigh twelve ounces, and many weighing less than one ounce. So minute are some of these castings that the moulding sand must be sifted in order to discover all the results of a day's casting. The finish applied to some of these articles, moreover, is such that one would hardly suppose them to be castings at all, emery wheel and tumbling barrel work having completely disguised their character.

EVEN into the Isle of Man, known to many by little more than Hall Caine's pathetic stories, has electric railway construction penetrated, and a road now runs from the village Laxey almost to the summit of Snaefell, the highest mountain in the island. The actual height ascended is 1820 feet in a total length of about 4¾ miles, making an average grade of about 1 in 12. The line, which, by the way, is intended solely for the convenience of tourists wishing to enjoy the natural beauties of the district, is laid out on what is known as the Fell system, with a central rail gripped by horizontal wheels in addition to the ordinary rails and wheels. The electric current is carried by an overhead wire and is taken off to the cars, not by the conventional trolley device, but by a framework arrangement of the kind used on some of the German electric roads, and shown in the little sketch of one of the cars which is given on this page. On the steeper portions of the line the central rail is utilized for tractive purposes, as well as serving for the safety brakes through the whole length. The horizontal wheels on each car are worked by separate motors. The power station is located about 2¾ miles from Laxey, and at Laxey itself there is, besides, a large accumulator

THE SNAEFELL MOUNTAIN RAILWAY.

station for absorbing the spare current generated by the dynamos, and for distributing it to the line as the load may require. The cars are 35 feet long, with seating capacity for about 48 passengers, and each car is carried on two four-wheeled bogies. Each axle is driven by a motor. The main power station contains four Lancashire boilers, 26 feet long and 78 inches in diameter, working at 120 lbs. pressure, with a capacity of 700 horse-power, and five compound horizontal engines, each independently driving a dynamo. The whole of the electric plant was designed and built by Messrs. Mather & Platt, of Salford, Manchester, England.

THE amount of power expended in playing on a piano has recently been figured out in a way which, if not altogether accurate, is at least interesting. Commenting on the statement made

that "it requires more force to sound a note gently on this instrument than it does to lift the lid of a kettle," the *American Art Journal* says that this is "easy to verify if one takes a small handful of coins and piles them on a key of the piano. When a sufficient quantity is piled on to make a note sound, they may be weighed and the figures will be found to be true. If the pianist is playing fortissimo, a much greater force is needed. At times a force of six pounds is thrown upon a single key to produce a solitary effect. With chords the force is generally spread over the various notes sounded simultaneously, though a greater output of force is undoubtedly expended. This is what gives pianists the wonderful strength in their fingers that is often commented on. A story used to be told of Paderewski, that he could crack a pane of French plate glass half an inch thick, merely by placing one hand upon it, as if upon a piano keyboard, and striking it sharply with his middle finger. Chopin's last study in C-minor has a passage which takes two minutes and five seconds to play. The total pressure brought to bear on this, it is estimated, is equal to three full tons. The average 'tonnage' of an hour's piano-playing of Chopin's music varies from twelve to eighty-four tons. Wagner has not yet been calculated along these lines."

ELECTRIC heating on a probably larger scale than has yet been adopted anywhere else is to be used in the Carmelite Monastery, at Niagara Falls, where a plant for that purpose is now being installed. It is not intended to heat the entire institution in this way, but, at any rate, a sufficiently large part to make the undertaking a decidedly noteworthy one. As might be supposed, all the power used in the building will be electrical, but the electrical cooking apparatus, the electrical laundry dispositions, and the electrical means for heating some of the rooms will be the things of paramount interest. Electric heating has not yet become so general as to make it an everyday affair, and the practical results which will be obtained in this instance will therefore command the widest attention.

SPEAKING of things electrical brings to mind the fact that an elevator worked by electric power has recently been built for the Ottawa Canoe Club, Ottawa, Ont. Owing to the great rise of the Ottawa river every spring, the boat house is situated a good height above the water level the greater part of the year. The transfer of the boats from the house to the water, and *vice versa*, was thus extremely difficult, and to obviate these drawbacks there has been erected a framed gangway, with a skeleton car, an ordinary worm-geared hoisting drum, and a 3-kw. 500-volt Edison motor. The motor is belted to a countershaft, which, in turn, is belted to the shaft carrying the worm. The car stops automatically at the top and bottom of the allotted course. Mr. Dion, of the Ottawa Electric Company, and treasurer of the club, designed the arrangement.

DRAWN BY C. N. COCHIN, 1777 ORIGINALLY ENGRAVED BY A. H. RITCHIE.

Benj. Franklin

Electrical Number.

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MUNICIPAL LIGHTING FROM UNDERGROUND MAINS.

By Edwin J. Houston, Ph. D., and A. E. Kennelly, Sc. D.

COMFORTable personal existence, in any of our nineteenth-century densely populated centres, is dependent not only on the ease with which intelligence can be transmitted, but also on the facilities with which light, heat and power can be distributed.

Prior to what may be regarded as the commercial advent of electricity, the means employed for the transmission of intelligence were practically limited to the private messenger or the public mail, and, for the distribution of light, heat and power, to the gas mains. It is true that to a small extent the distribution of heat, in large cities, has been attempted by the use of underground steam pipes, and the distribution of power, by the use of water mains, but such distribution of heat and power, has never been employed to the same extent as that of light.

In municipal, as in private life, it too frequently happens that blessings fail to bring unalloyed comfort. The facility with which electric energy can be transmitted from one place to another, the readiness with which it can be transformed, coupled with the cheapness with which mechanical energy can be changed into electrical energy, have placed at our disposal means for the distribution of light, heat and power that, in convenience and economy, are far in advance of the old methods. Though the advent of the electric era has thus done much to render life more comfortable, yet the marked advantages which the new agent possesses over its rivals, have brought about such an exceedingly rapid multiplication of overhead conducting circuits that in some places they threaten to pass from a public nuisance to a public evil.

In place of the comparatively few telegraphic wires of, say, twenty years ago, there is now in many cities an intricate network of aerial conductors for telegraphy, telephony, fire and burglar alarms, messenger calls, light, heat and power circuits, that threatens, in some sections, to cut off the light of day, to say nothing of the danger to life and the interference offered to the extinguishment of conflagrations.

The problem of placing all electric conductors underground is by no means as simple as it may, at first sight, appear. It is easier for municipal authorities to decree that all wires shall be buried,

in accordance with some one or other system of underground circuits, than it is to practically carry out the mandate. Even if the streets of large cities were not already occupied by existing systems of sewers, gas and water mains, the difficulty of the problem would be sufficiently great. Still, the necessity for placing the wires underground is urgent, and the solution of the problem will ensure advantages so marked as to warrant, in the case of large cities, any reasonable expense.

It is not the intent of this article even to suggest the best means for carrying this desideratum into effect. Whether it can best be done by subways, by underground conduits, or by simply burying the conductors, we will not here discuss, but will rather content ourselves with pointing out the manner in which the distribution of circuits, intended for light, heat and power, has actually been carried out in the large cities of the United States.

It is interesting to note that the first electric circuit experimentally tried in this country fifty years ago, *i. e*, that of Morse with his first telegraph, was of the underground type. Owing to the difficulty experienced at that time in the manufacture of insulated wires this circuit was unsuccessful, and was replaced by an aerial wire. After that time all telegraphic circuits, except at river crossings, employed aerial wires for many years.

It is improbable, however, that the failure of this first underground circuit is to be held responsible for the rapid growth of the forests of overhead conductors that exist in nearly all large American cities to-day. A sufficient reason for such growth is to be found in the greater convenience and economy of aerial as compared with underground conductors. And even if it could be demonstrated, as doubtless it could in many cases, that the highest economy, in the long run, is on the side of underground wires, still, so long as the apparent economy is on the other side, the wires will continue to be strung overhead. Municipal legislation, having regard, as it should, for the greatest good of the greatest number, is necessary to ensure the removal of overhead conductors.

CROSS SECTION OF A CABLE CONDUIT FOR ELECTRIC TRANSMISSION LINES AT NIAGARA FALLS.

Various plans have been proposed for effecting the burial of conductors. These may practically be arranged under three heads, namely, the subway, the conduit, and the buried tube or conductor. The first two provide means whereby the conductor, after having been once laid, can be removed from the ground without again tearing up the streets. The subway consists essentially of an

Edwin J. Houston.

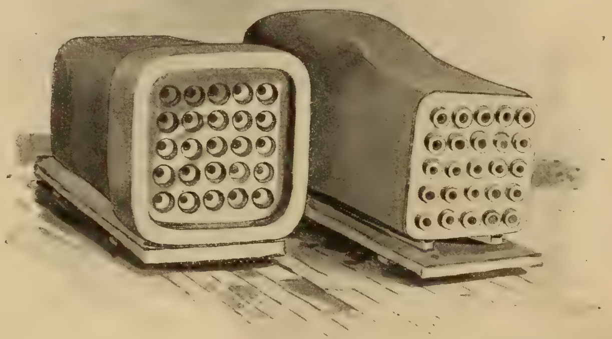
PROFESSOR EDWIN J. HOUSTON has an international reputation as an electrical engineer, and his name, coupled with that of Professor Elihu Thomson, is well known on both sides of the Atlantic.

A. E. Kennelly

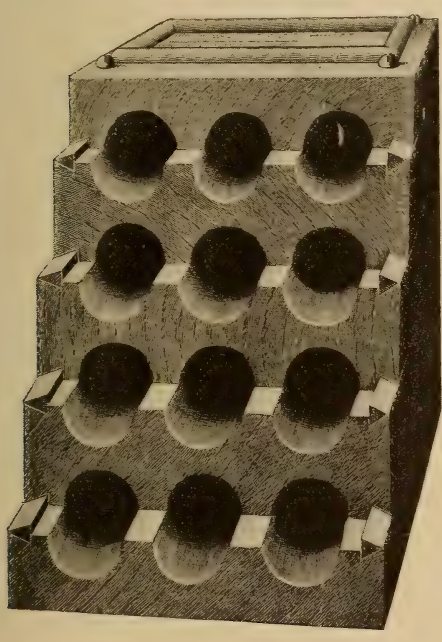
A. E. KENNELLY was, for several years, electrician in Edison's laboratory and also served as consulting electrician to one of the large electrical companies. He stands to-day among the foremost men in the electrical profession.

underground tunnel of sufficient dimensions to permit the passage of a workman, for the introduction, inspection and repair of its conductors. A conduit differs from a subway in that it only permits the introduction or withdrawal of the wires at the manholes.

While ideally the subway is unquestionably the best form, and affords the best means for the use of underground conductors, yet, under most circumstances, its cost would be practically prohibitive. It has been estimated, for example, that the construction of such a subway in the city of New York would cost about $400,000 (£80,000) per mile. This excessive cost arises not only from actual construction, but also from the expensive preparatory work required for replacing existing systems of sewers, gas and water pipes and electric conductors. For this reason, subways have not come into extended use for the reception of mains for the municipal distribution of light, heat and power.



EARTHENWARE CONDUITS.



A WOODEN CONDUIT SECTION.

Perhaps the most extensive system of subways for this purpose is in Paris, where, prior to the multiplication of electric circuits, subways had been provided for the reception of the sewers, the gas and water mains, as well as for some few electric conductors. So great, however, has been the increase in the number of electric conductors in recent years, that the subways have been insufficient to afford them the proper accommodation. In London there are four or five miles of subways which are said to have cost £28 000 per mile.

In the United States the use of subways has been more limited. The city of Detroit, Mich., where a few comparatively short subways have been constructed, affords, perhaps, one of the best examples of the subway system. The subways are six feet six inches in height, three feet three inches in width, and are elliptical in cross section. The conductors, in the form of insulated cables, are suspended on brackets supported on the walls. Incandescent lamps are provided for lighting the subways when required.

At Niagara a subway about half a mile in length has been constructed for

ARC LAMPS ON A METROPOLITAN STREET.

the purpose of carrying the cables for the electric transmission of power from the Niagara Falls Power Company's plant to the Pittsburgh Reduction Company's works. Some idea of this subway may be obtained from the illustration on page 180. Brackets are provided on the sides for the support of the cables.

The conduit system assumes a great variety of forms. Since the conductors that are inserted in conduits are, in all cases, carefully insulated, and, indeed, generally provided with a protecting covering of lead, it is not necessary that the material of the conduit be insulating, especially when it is remembered that conduits are very apt to contain water. The materials required for the construction of conduits are, therefore, selected rather for their strength and durability, than for their insulating qualities. Space will permit us to mention only a few of the more important forms of conduits. These are constructed of earthen-ware, wood, or iron with or without cement.

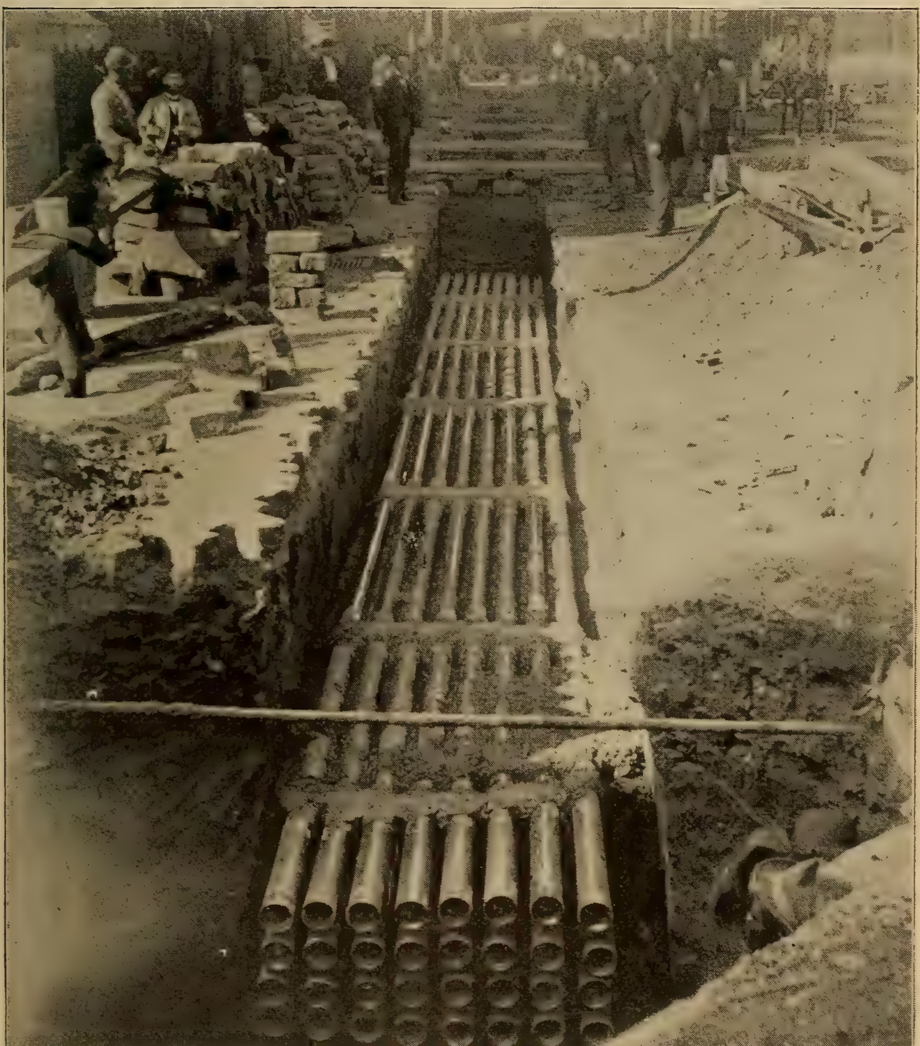
Earthen-ware conduits are made either in single tubes, or, as is more frequently the case, in blocks containing a number of tubes. In the earthen-ware conduit shown on the preceding page, twenty-five ducts are provided in each section. The tubes are glazed for the purpose of ensuring a smooth internal surface, which will prevent injury to the wires when drawn in. They are laid end to end in a trench, and the joints are afterwards closed with cement.

Wooden conduits are made in a variety of forms, one of the commonest being shown also on the preceding page. In order to prevent rapid decay, the wood is subjected to some preservative process, usually creosoting. For convenience, the conduits are made in tiers; the cables which are drawn through these tubes being almost invariably lead lined, require to be protected from the corrosive action of impure creosote by some suitable coating.

Iron pipe conduits are largely used in the United States. They are either of standard gas pipe, laid in hydraulic cement, or consist of thin sheet iron tubes, lined internally with cement.

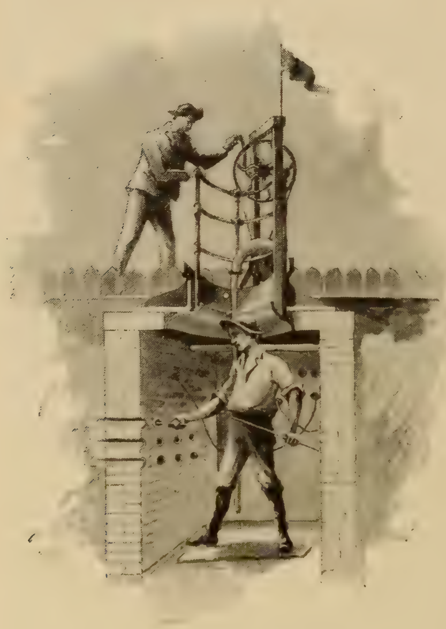
Sometimes, in addition, they are laid in a bed of cement. There are nearly two hundred miles of conduit in use to-day in New York City, while the total length of ducts, at present in use in America, is estimated at nearly 6000 miles.

Since conduits are buried in the streets, man-holes have to be provided at suitable intervals, usually at street intersections, to permit the introduction or removal of the conductors. In New York, these man-holes are generally nine feet deep and five feet wide, and are closed with a double covering of cast iron. When conduits are located in the neighbourhood of leaky gas mains, explosive mixtures of gas and air are liable to accumulate in them, and the accidental ignition of this mixture has caused serious damage. To prevent these explosions, forced ventilation of air through the conduits is sometimes employed.



CEMENT-LINED IRON CONDUITS.

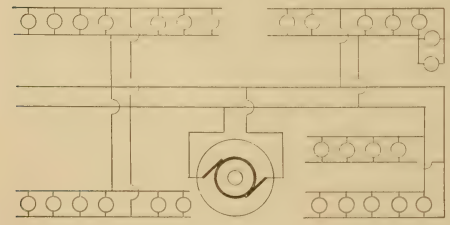
In order to draw wires into the conduits, short jointed rods of wood or iron are employed, of sufficient length, when jointed together, to extend from one man-hole to the next, usually be-



A MANHOLE FOR IRON PIPE CONDUITS.

tween two hundred and three hundred feet. The wires are then attached to the ends of the jointed rods and are drawn through the conduit, after which the cable is drawn in.

Municipal electric lighting from underground mains, as actually carried

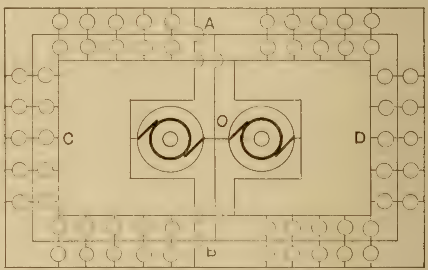


THE TWO-WIRE SYSTEM.

out in the United States, has divided itself along two sharply marked lines,—the conduit system, and the tube system. Each possesses certain advantages and disadvantages. The conduit system provides a number of ducts, through which conductors may be run as occasion may require. The tube system, although not possessing the flexibility of the conduit system, nevertheless, has often the advantage in economy of cost. In this system, insulated conductors, protected by an iron covering, are buried in the ground. The disadvantage of this system lies in the fact that the street requires to be dug up for the repair or change of the conductors.

The rapid growth of the conduit system of underground conductors may be judged from the fact, that in the United States, in 1882, there were not more than ten miles of underground conduits, while at the present time the aggregate length of all underground conductors is about two hundred thousand miles.

The principal commercial system of municipal mains in use in the United States for incandescent lighting, is called the three-wire system of distribution. The original, or two-wire system of distribution, consists essentially of two main conductors, one positive and the



THE THREE-WIRE SYSTEM.

other negative, with the lamps connected between them, as represented on this page. In reality the lamps are seldom directly connected across the mains. The street mains are laid in trenches, which, in dense centres, are located on each side of the street. Where it is required to supply a house, a short service connection is tapped from the mains, and usually led into the cellar, to a main cut-out or switch, for turning the current off or on the house. From the cellar of the house, positive and negative conductors,

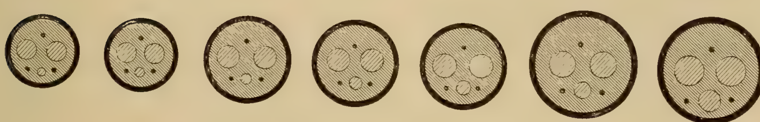
called risers, pass to the different floors. At each floor the risers connect with positive and negative mains, usually running along the halls, and from them positive and negative sub-mains are led into the various rooms. The incandescent lamps are connected between the wires of these various branches.

Such a two-wire system is represented on the opposite page, where a dynamo is connected with a pair of mains, from which branch mains are carried, connected to groups of lamps on each side of the mains. When the lamps are situated at only a short distance from the dynamo, that is, when the area over which the lighting to be distributed is comparatively concentrated, the cost of the copper, which is required in the conductors, does not form a large proportion of the total expense of the installation. When, however, a comparatively large area has to be covered, so that the average lamp is comparatively far from the dynamos, the amount of copper which has to be used, in order to maintain uniformity of pressure over the mains, becomes a seriously large item in the capital account. Just as a given amount of water-power may be carried, either at a high pressure and small volume through a small pipe, or at a low pressure and large volume through a large pipe, so a given amount of electric power, sufficient for the lighting of a definite number of lamps, can be distributed either with small conductors and small currents at a high electrical pressure or voltage, or with large heavy conductors and large currents at a low electrical pressure.

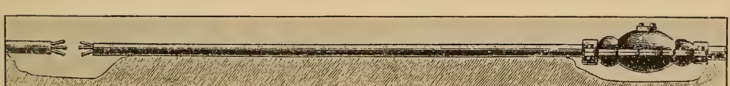
It is important, therefore, to employ as high an electrical pressure as possible in the distribution of incandescent lamps. The pressure, however, for which incandescent lamps can be manufactured is, or rather has been until lately, limited to about 115 volts; that is to say, lamps of a given candle-power have been made for any pressure from 10 volts up to 115. The higher the pressure, however, the longer and thinner the incandescent filament has to be, so that the difficulties of manufacturing lamps, with long and fine filaments, have been met in commercial practice by the limitation of 115 volts.

This has, consequently, limited the pressure which could be employed in the street mains to approximately 115 volts, unless, of course, some form of pressure-reducing device could be introduced in each house between the lamps and the street mains. Alternating-current system, of electric distribution, actually employ such a device in the shape of an apparatus, called the alternating-current transformer, which

SECTIONS OF MAIN TUBES.

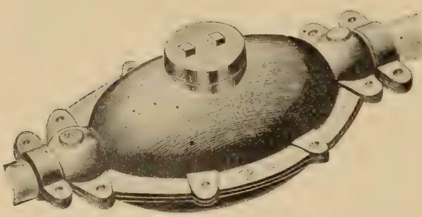


SECTIONS OF FEEDER TUBES.

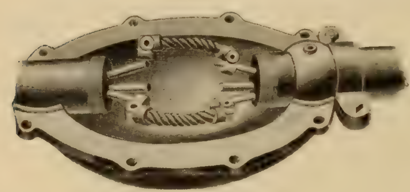


AN EDISON TUBE WITH ITS COUPLING BOX.

enables the mains to be supplied through small wires at a pressure of 1000, or 2000 volts, and yet permits the



AN EDISON COUPLING BOX COMPLETE.



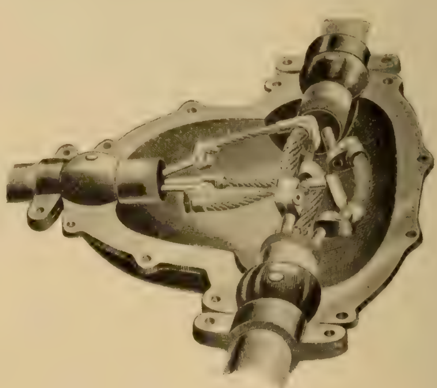
THE LOWER HALF.

house wires to be supplied at a reduced pressure, namely, 50 or 100 volts.

Such systems are called high-tension systems in contradistinction to those in which the lamps are supplied directly from street mains, and which are called low-tension systems. The low-tension systems, however, are not limited to the highest pressure at which a lamp can be made to operate commercially. If, for example, incandescent lamps were always connected in pairs, so that the current passed through the two lamps of each pair in succession, then it is evident that the pressure between the mains would be doubled, or increased to 230 volts. This would reduce, by 75 per cent., the weight of copper which would be necessary to employ in the mains for a given loss of pressure or energy, since the amount of copper which must be employed, under given circumstances, varies inversely as the square of the pressure at which the energy is delivered; so that with 230 volts, four times less investment in copper would be required than with 115 volts. This method would possess, however, the great practical disadvantage of always requiring two lamps to be turned on or off together.

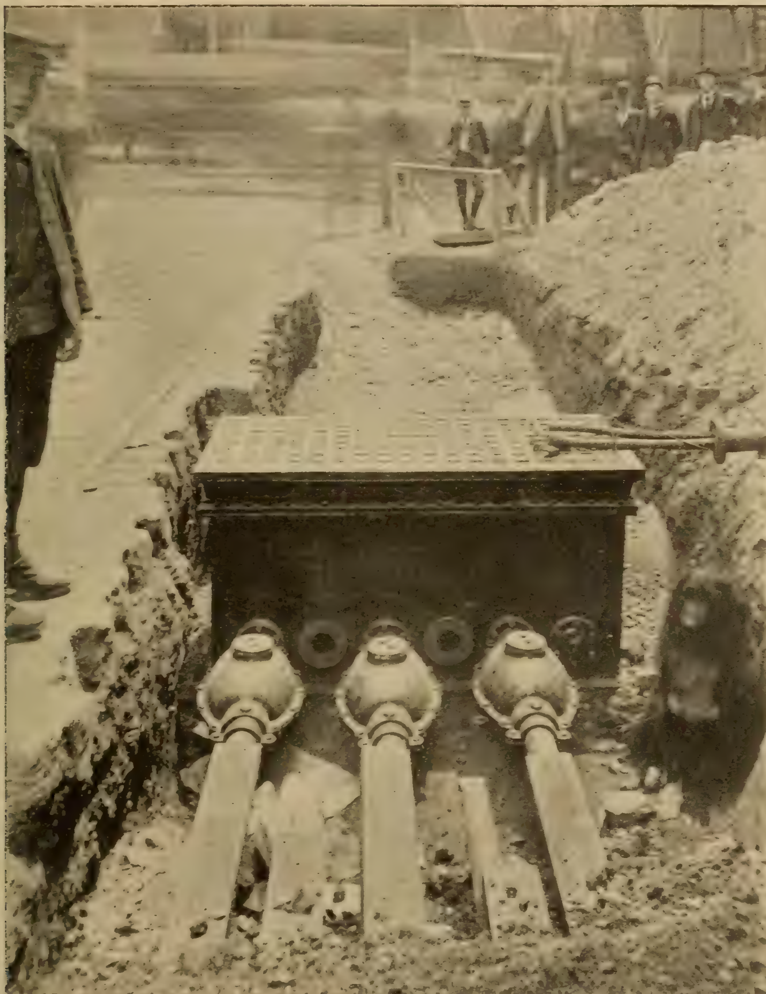
The three-wire system, an invention of Edison, was designed to obtain the advantages of double pressure, with control for each individual lamp. In this system, as the name indicates, three wires are employed. The double pressure is obtained by coupling two dynamos in series, like two voltaic cells, so that the pressure, of the two combined, is twice that of either. The third or neutral wire, as it is called, is carried from the common connection of the two dynamos through the system, and is connected between all the pairs of lamps, as shown in the diagram on page 188. With this arrangement it will be seen that if all the lamps on the positive side of the system were turned off, and all the lamps on the negative side were turned on, the negative dynamo would be working at full load, between the neutral and negative mains, while the positive dynamo would be running idle, or without supplying current. For this purpose it would only be necessary that the neutral wire should have the same size as the positive or negative wires.

Since such a condition of load could



A TEE COUPLING BOX.

never arise in practice, the neutral wire has to carry only a small share of the current in either the positive or negative mains. If the load were exactly balanced, the same number of lamps being on the positive as on the negative side, there would be no current on the neutral wire returning to the dynamos,



TUBES ENTERING A JUNCTION BOX.

although there might be current flowing through the neutral main in the streets, passing locally from one lamp to another.

In the mains, therefore, the positive, negative and neutral conductors are made of the same size, but in the wires connecting the street mains with the distributing or central station, the neutral has only one-third of the weight of each of the outside wires. This is shown in the drawing on this page representing the cross sections of feeders and mains. The resulting economy of copper, required under practical conditions in the use of the three-wire system, is about 65 per cent., so that only 35 per cent. is required of that necessary for the simple two-wire system.

Before describing the system of under-ground tubes employing the three-wire system, a word of explanation is necessary concerning what are called feeders. This was another notable invention of Edison, for reducing the ex-

A CIRCULAR JUNCTION BOX.

penditure of copper in a commercial system of incandescent lighting. No device is so sensitive to variations in electric pressure as the incandescent lamp. It may be a matter of surprise to many to learn that an ordinary 16-candle-power incandescent lamp of good manufacture, will have its candle-power increased to about 18 candles by a rise in pressure of but two volts, from, say, 114 to 116 volts, while its lifetime will, probably, be reduced about 33 per cent. in consequence. It is, therefore, necessary, both for maintaining uniformity in brilliancy and uniformity in the duration of lamps, that the pressure in the mains, at the house service connections, should be maintained as nearly uniform as possible.

It is a well-known fact that in pipes or mains for the distribution of both gas and water, the pressure in the mains is uniform over the entire distribution system only as long as no gas or water is actually flowing through the pipes; *i. e.*, while it is not being supplied to the consumers. As soon, however, as the water or gas begins to flow, to meet the consumers' demand, a decrease, or drop, in pressure, occurs from the reservoir, or point of supply, where the pressure is highest, to the most distant consumption point, where the pressure is lowest, intermediate points possessing an intermediate pressure.

Analogous phenomena present themselves in the case of electric mains. The pressure or voltage is uniform all over the system only so long as no current is flowing. As soon as consumers turn on their lamps and current flows through the system, a drop of pressure occurs from the central station, where the pressure is highest (say 250 volts across the outside wires, or 125 volts on each side to the neutral), to the most distant consumption point, where the pressure is lowest (say only 180 volts, or 90 on each side); while intermediate consumers would obtain an intermediate pressure. The lamps, would, therefore, be very dull in the distant houses, and very bright in the houses near the dynamos. For example, in the figure representing the three-wire system before referred to, the pressure would be highest at *A* and *B*, where the dynamos were connected with the mains, and lowest at *C* and *D*, the most distant points.

The only way which existed, before the invention of the feeder system, of reducing this objectionable drop of pressure, was to employ heavier and more expensive conductors, so as to reduce the amount of drop in the same way that the use of larger gas and water pipes would diminish the drop of water pressure in them. By the use of the ingenious device of feeders, however, it becomes possible to transmit currents to comparatively great distances, without serious difference in pressure among the lamps connected with the system. This was accomplished by employing mains for the sole purpose of supplying the lamps, which mains were never directly connected with the dynamos, and of introducing special conductors; namely feeders, to connect the dynamos with the mains, said feeders having no lamps directly connected to them.

Thus in the figure, the three wires leading from the dynamos at *O* and *A*, and also *B*, may be considered as feeders, since they have no lamps connected to them, while the triple set of conducting wires, *A*, *B*, *C*, *D*, constitute the mains, to which the lamps are all connected. It is thus possible to have a heavy drop of pressure in the feeders without sensible difference of pressure in the mains, provided the drop of pressure in the various feeders is uniform.

For example, it would be possible to have the pressure between outside conductors 260 volts at the central station, and 230 volts at both *A* and *B*, where the feeders join the mains, representing a drop of 30 volts in each set of feeders, while the lowest pressure at *C* and *D*, might be only 228 volts, representing only 2 volts drop of pressure in the mains. This would enable comparatively small wires to be carried from *O* to *A*, and from *O* to *B*, and yet maintain a uniform pressure over the system of mains, while otherwise, if lamps were connected directly across all conductors, it would

be necessary to have larger wires from O to A, and from O to B, than in other parts of the system. In practice, when currents have to be carried to districts a mile or more from the central station, it is at once evident that the problem could not be dealt with commercially, on the low tension system, without the use of feeders.

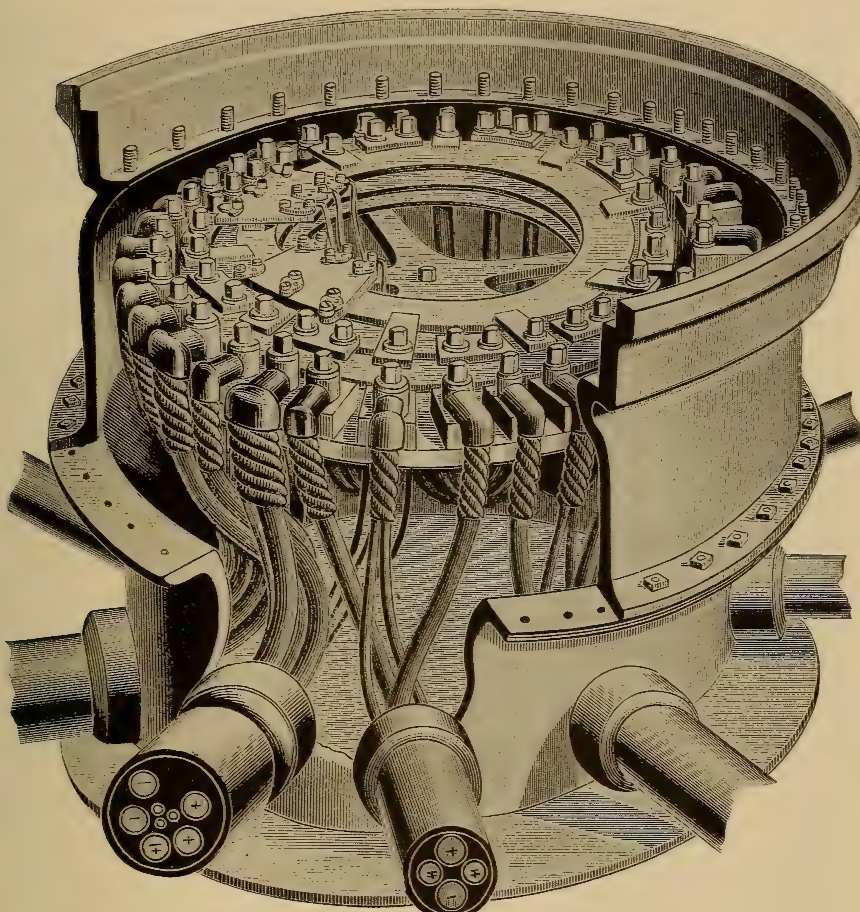
JOINTING EDISON TUBES IN A STREET TRENCH.

The tubes containing the conductors for the three-wire system are made as follows :—Rods of copper, having the required cross-section are cut off into lengths of 20 ft. 4 inches. In order to prevent them from coming into contact with each other, they are each wrapped with a loose spiral of rope, and are then laid side by side in a triangular pile, and spirally wrapped with a fourth rope. The rope, however, is not relied on to insulate the wires from each other, the bundle of rods being placed in an iron tube, which is filled with a melted bituminous insulating material. The two ends of the pipe are then plugged, leaving the three copper rods projecting about three inches from each end.

It is obviously necessary, when laying a line of such tubes, to make a joint every twenty feet. This is done by tightly bolting a special form of cast iron box, called a coupling box, shown on page 187, on the right hand side of one section of tube. The details of the lower half of a coupling box with one conductor connected across, as well as the appearance of the coupling box complete, with its cover in place, will be seen from an inspection of the figures on page 188.

To make a joint between the conductors, their ends are first cleaned, and the collars of a flexible copper rope connection are forced friction-tight over them, as shown, the connection being finally soldered. There is thus secured, not only a good electric connection between the ends of the copper rods, but also a flexible joint, which permits of a considerable range of expansion and contraction.

The actual appearance of a street trench containing five lines of the tubes, during the process of jointing, is represented on this page. It will be observed that the flame of a gasoline torch is being applied by one of the workmen to the copper connectors, in order to solder the joints. The appearance of three tubes, with their coupling boxes completed, ready to enter a large junction box, is also represented on

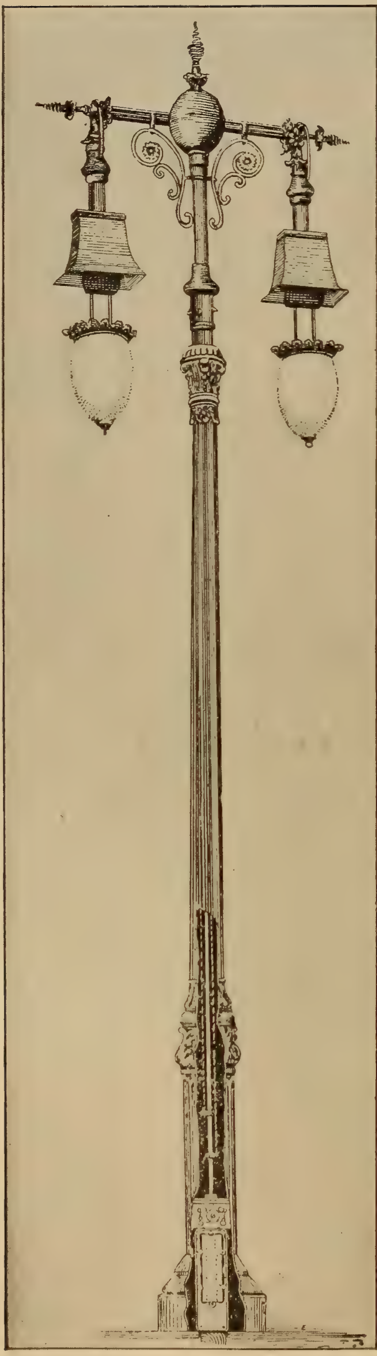


THE INTERIOR OF A JUNCTION BOX.

page 189. The tops of the coupling boxes are screwed down after the interior has been filled with the melted bituminous compound.

When it is desired to tap a street main, in order to connect a house service and supply a house, a hole is dug in the street at the nearest coupling box, which is then replaced by a T-box, such as that represented on page 188. There it will be seen that besides the connection of positive, negative and neutral rods, there are three smaller connections, a positive, a negative and a neutral, passing to the smaller tube or house service, on the left.

At street corners, and wherever feeders are connected to mains, a special form of circular junction box is employed, of a size depending upon the number of tubes meeting in it. The surface of this cast iron box is level with the surface of the street, while the tubes enter at the lower level. The external and internal appearance of the boxes is represented on page 190 and on this page. The ends of the rods projecting from the tubes into the boxes, are led by flexible cables to three brass horizontal insulated rings, insulated from each other, and supported near the under surface of the cover or lid. One of these rings is for connection with the positive conductors, another


ARC LAMPS FOR STREET ILLUMINATION.

for the negative conductors, and the third for the neutral conductors. Each of the respective conductors being connected to its own ring, is in connection with all the other conductors leading to that ring. By this means a permanent connection is maintained between the feeders and the mains radiating from the box.

The junction boxes are kept water-tight by the use of a double cover. The first cover is bolted down upon the ring of bolts shown, over a strip of soft rubber, and a melted compound is then poured over its surface so as to form an impervious covering. The second or upper lid is not water-tight, and is readily lifted by the aid of a suitably shaped tool. In the illustration on page 190, a junction box is represented with its tube connections exposed and a joint being made in one of them.

Starting from the various central stations which supply the network of mains with current, we could follow the feeders to their various feeding points where they ramify and connect with different parts of the system. The mains then pass through the streets and give off service connections as they pass, while within the houses are the risers, the sub-mains and the branches as already described.

It will be readily understood, that in a densely-populated city like New York, the requirements of electric light, heat and power, as well as for telegraphic, telephonic and signalling systems, are very great, so as to necessitate a perfect network of conducting wires. Happily for the safety, as well as æsthetic beauty of that city, the municipal authorities have caused the overhead wires to disappear from its better portions. Naturally, therefore, the streets contain a mass of underground wires. The arc systems, together with the telephone, telegraph, messenger calls, printing telegraph and burglar alarm systems all require a multitude of wires.

The total length of Edison tubes is, approximately, 200 miles, with about 1100 junction boxes. The total number of incandescent lamps connected with these mains is a little over

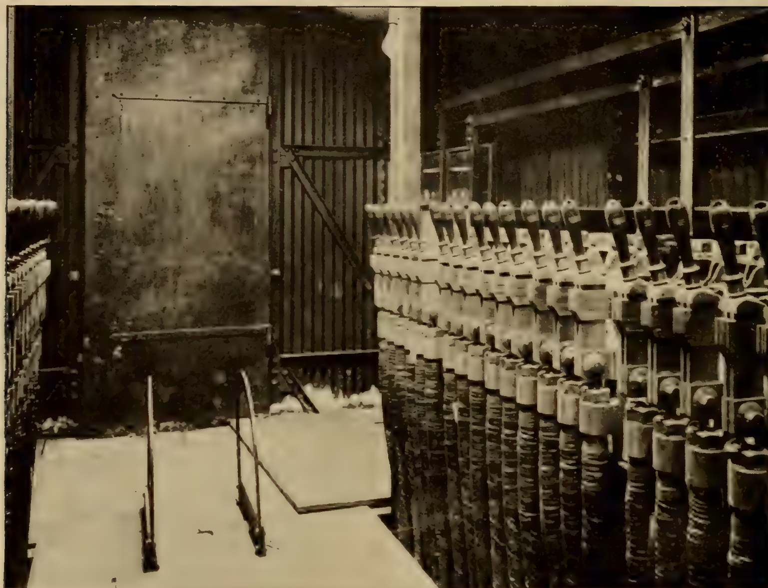
250,000. There are also operated from these mains 3190 arc lamps, of the type represented on page 194, and 10,951 horse-power in motors. The lamps are always connected in series pairs, in order to utilize advantageously the pressure between the neutral wire and either the positive or the negative main. this load occurs at a time in the evening, about 7 o'clock, when the motor load has practically disappeared; for, if all the lamps and the motors had to be operated simultaneously, about 28,000 H. P. would be required to supply them.

The ordinary 16-candle-power incan-

INTERIOR OF THE ENGINE ROOM OF THE CHICAGO EDISON CENTRAL STATION.

Since each arc lamp requires about 10 ampères of current, and about 50 volts pressure, two in series require about 100 volts pressure.

Rating the total horse-power of all the motors connected with the circuit, the maximum load taken collectively by all the six stations furnishing the current, during the darkest day of 1894, was, approximately, 10,000 H. P. in electrical energy at the various dynamo terminals. It will be understood that descent lamp takes from 1-15th to 1-11th of an electrical horse-power at its terminals, or, in other words, one horse-power, expended in electrical energy, will supply from 11 to 15 ordinary 16-candle-power incandescent lamps when close to the dynamo, according to the quality of the lamps. Reckoning one horse-power in motors, as 15 incandescent lamps, and each arc-lamp as equivalent to ten incandescent lamps, the total load connected to the



THE INTERIOR OF THE CHICAGO CABLE HOUSE.

mains of New York City on October 1, 1895, was 433,890 sixteen-candle-power incandescent lamps.

The next largest system of underground mains in the United States is that of Chicago. This differs from that of New York in the fact that practically the entire lighting of the city is owned by a single company.

The system of mains for the three-wire circuits, employed by the Chicago Edison Company, is fed by five central stations. The distribution of the underground three-wire system in Chicago differs from that of New York, in that, in New York, all the mains are interconnected, while in Chicago they are arranged in three separate and distinct districts. A peculiar feature of the topography of these underground mains is that in two of the districts the tubes run through alleys in a single line, instead of through the main streets in a double line. The service wires enter at the backs of the houses, instead of at the fronts.

The alternating-current, high-tension system in Chicago is employed almost entirely for the electric lighting of the two-wire system, at a pressure of 1000 volts, reduced on the premises of the consumer, by alternating-current transformers, to a pressure of 100 volts. In a few instances the current is delivered at 1000 volts pressure to large transformers from which it is reduced in the secondary, or low-tension, circuit to 208 volts on a three-wire system of low-tension mains, with 104 volts on each side of the neutral.

The three-wire Edison system is operated by underground tubing, with the exception of 400 feet of tunnel under the Chicago River, through which cables are led. This tunnel was constructed for the purpose of carrying the current from one of the main central stations to the central portion of the city. The cable house into which the cables pass on emerging from the tunnel on the eastern side of the Chicago River is shown on this page. There the cables are connected to the feeder tubes passing through the streets. The illustration shows the switches which form the connection.

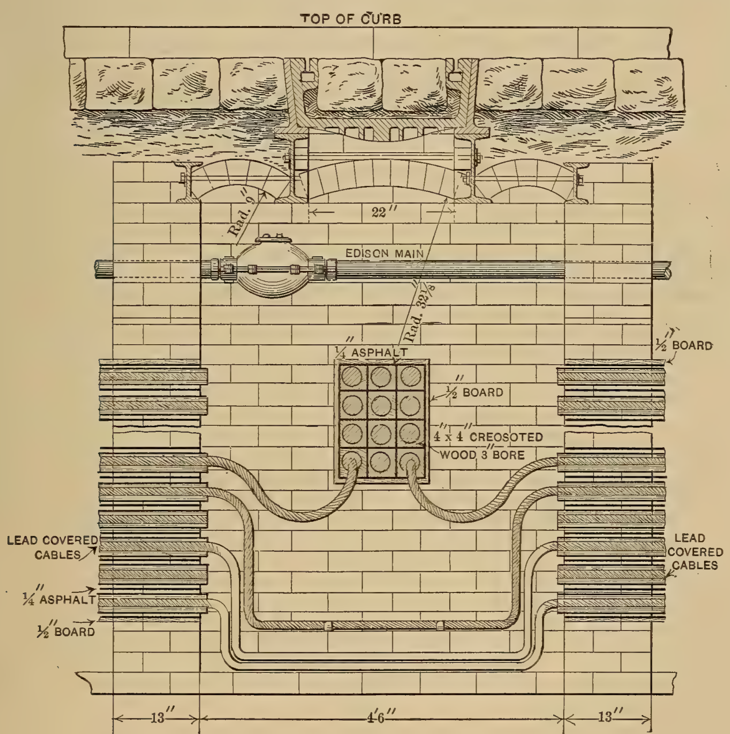
There are 99 miles of tubing, representing 297 miles of conductor in the

entire Chicago Edison system. The underground alternating-current system is operated by about 400 miles of cable, running through about 170 miles of conduit. In 1894, the total connected load of the entire system of five stations was 161,927 incandescent lamps, 4210 horse-power in motors, 1917 series arc-lamps, and 1707 low-tension arc-lamps, making a total equivalent of 269,150 sixteen-candle-power incandescent lamps. This load had grown thirteen fold in five years.

We have entered into detail concerning the particular character of the distribution of underground mains in these two cities, because their electric distribution systems are the largest in America. The system in Berlin, Germany, stands third in point of size, having in June, 1894, a total of 190,400 incandescent lamps and 1364 H. P. connected, making an aggregate equivalent connected load of 210,860 lamps.

In Philadelphia the low-tension underground system of mains consists entirely of tube, but its feeders consist of lead-covered, jute-insulated cables, running through wooden conduits. This arrangement possesses the advantage that if a feeder becomes overloaded, by reason of the growth of demand upon its area, it may be readily replaced without opening up the street trenches. The arrangement of tubes and cables at a manhole is shown on this page.

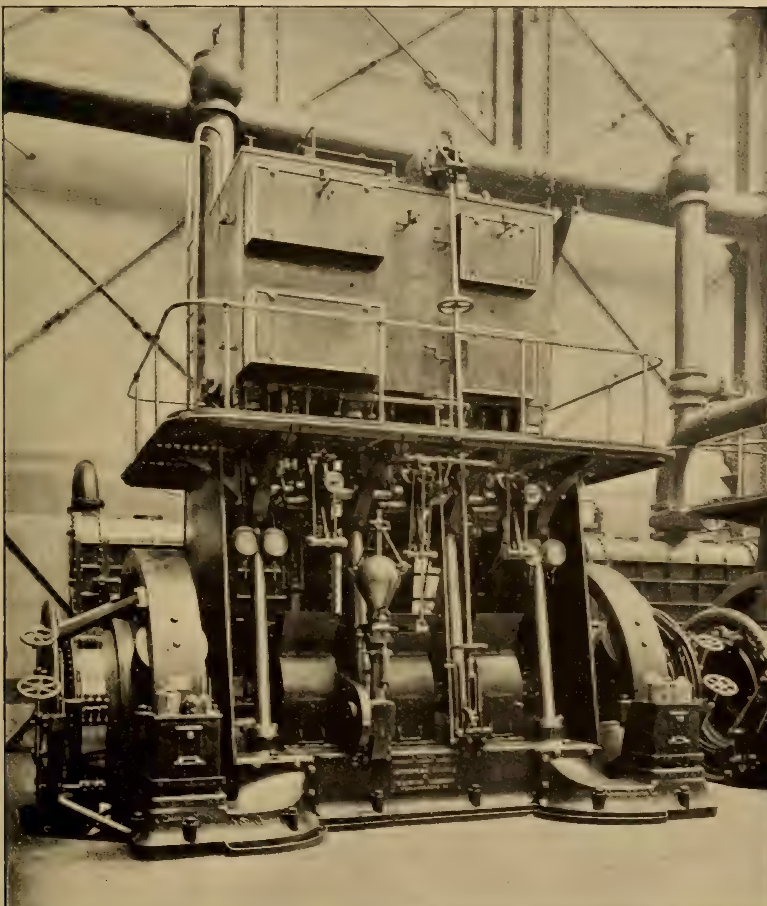
Coming now to the central station, where the electric current to be distributed through the mains is generated, we find, as would naturally be supposed from the magnitude of the operations, machinery evidencing a high type of engineering. In the most recent types of central station for the generation of electric power on a large scale, the steam engines are of the vertical, compound, marine type, with double or triple expansion. The



LONGITUDINAL SECTION OF MANHOLE WITH WOODEN CONDUITS IN PHILADELPHIA.

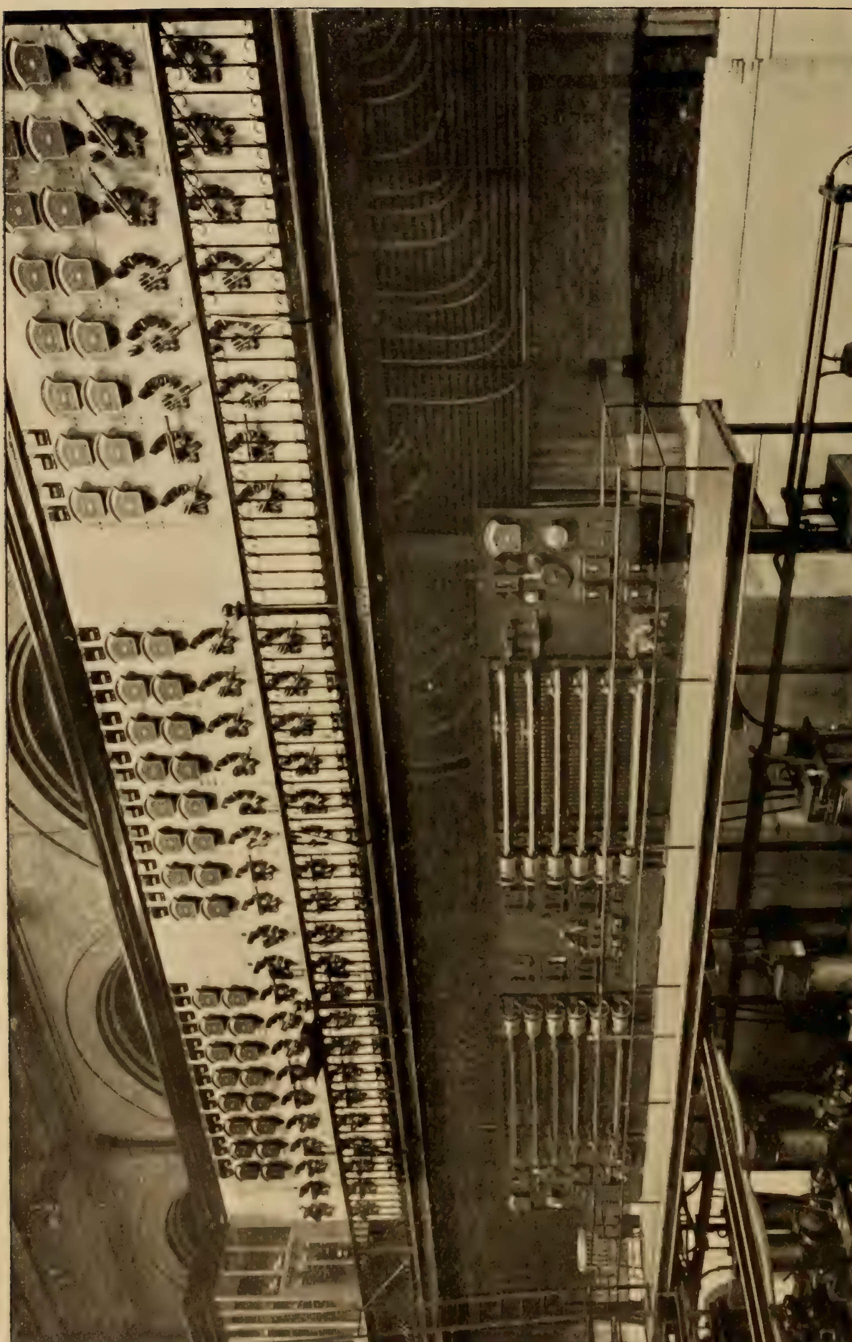
A BATTERY OF BOILERS IN THE CHICAGO CENTRAL STATION.

superiority of the marine type of engine for the economical development of power in large units has long been known. The dynamos are directly coupled to the main shafts of the engines, instead of being belted to fly wheels connected to them. Occasionally low-speed compound Corliss engines are employed.

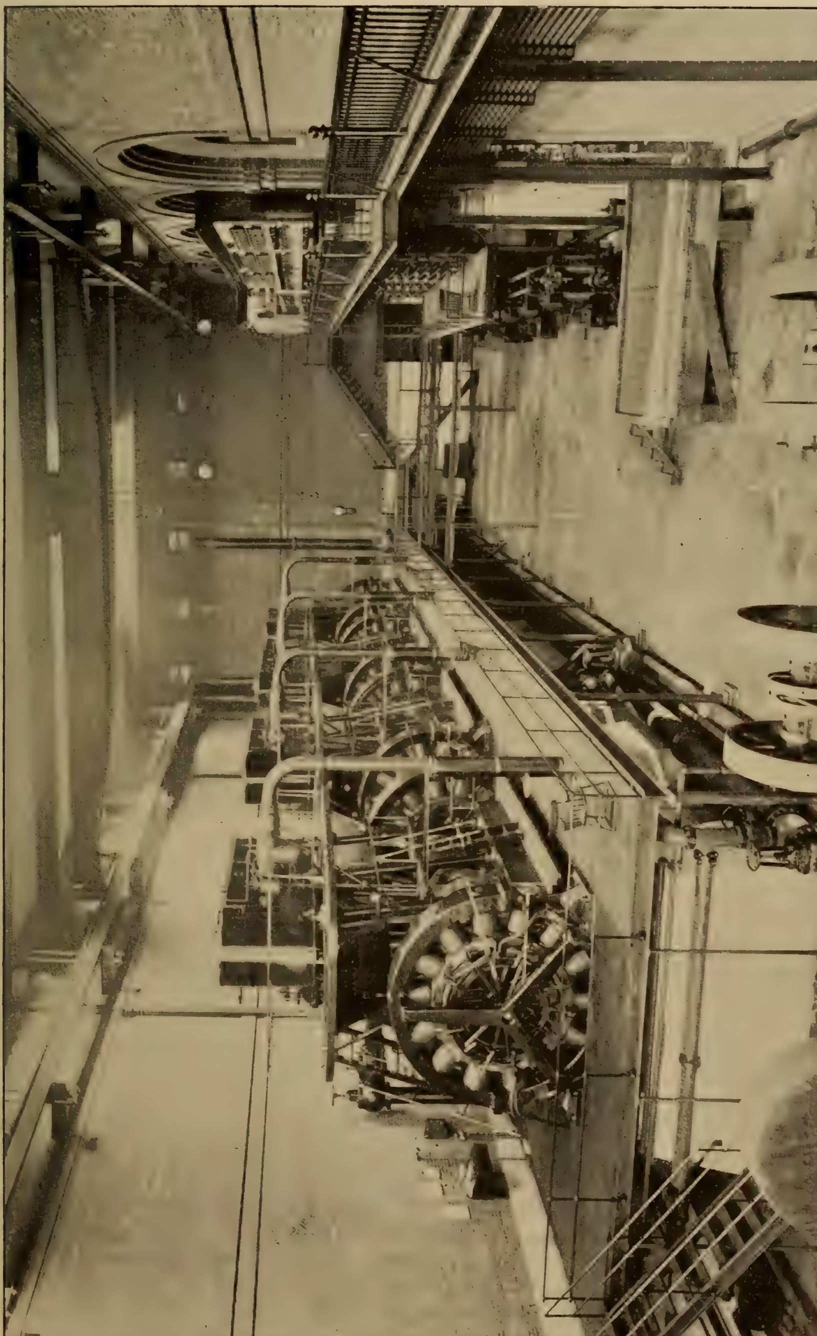


A 600 H. P. VERTICAL TRIPLE-EXPANSION ENGINE IN THE CHICAGO STATION.

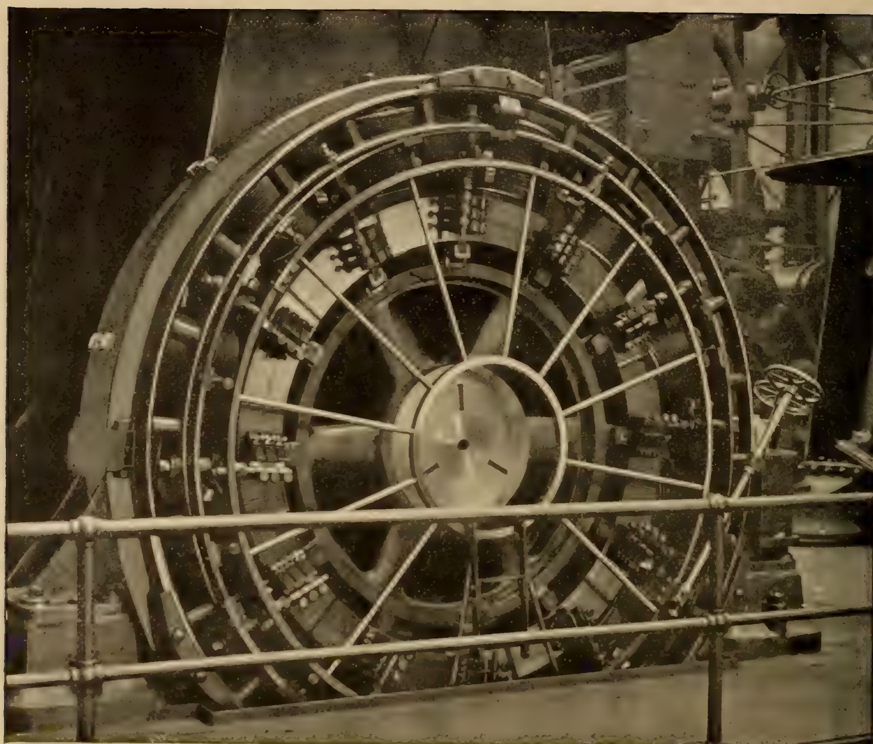
One of these vertical engines is shown on this page. It is a triple expansion engine of 600 horse-power, making 157 revolutions per minute, with a steam consumption of 13.5 pounds per horse-power-hour. It drives, on each side, a 200 kilowatt, or 268 H. P., multipolar dynamo, there being six poles in each field frame. In the illustration on page 202 of a 400 KW. (536 H. P.) 12-pole generator, the multipolar type of dynamo is represented in greater detail. The field frame, of steel, is mounted on the engine bed plate, and the armature is mounted on the engine shaft, so as to rotate in the cylindrical space formed by the field poles. Twelve sets of conducting brushes are held in the frame, so as to press upon the side of the armature and carry off the current to the bus bars, or main station terminal rods. These 400 KW. dynamos are



THE GALLERY SWITCHBOARD AT CHICAGO.



THE EDISON CENTRAL STATION AT BOSTON, MASS., U. S. A.



A MULTIPOLAR DYNAMO IN THE CHICAGO STATION.

each capable of continuously generating a current of 3000 ampères at a maximum pressure of 155 volts, representing a maximum activity of 465 KW.

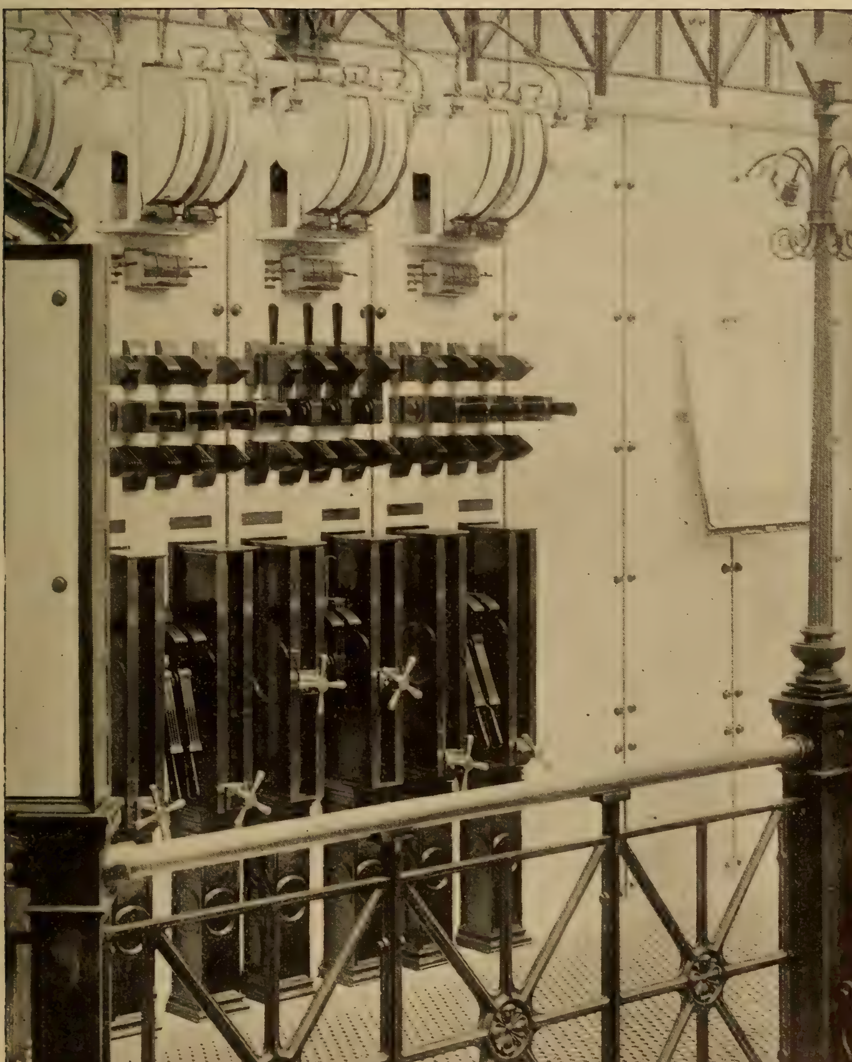
Each steam engine in a central station, with its attached dynamo or dynamos, constitutes what is called a power generating unit. It is a matter of great importance in the economical operation of a central station, that the size of the power units be judiciously chosen, since a large engine may be very economical at full load, and yet very uneconomical when worked on light loads. Moreover, the load on a station varies considerably with the time of the day, so that some of the generating units have to be withdrawn from service during part of the time. The arrangement of these units in the main station at Chicago is represented on pages 195 and 199. At the end of the engine-room is the gallery switchboard, from which the distribution of power is controlled, and on each side of the room are the generating units connected to their main steam pipes.

The gallery switchboard, shown on page 200, is so arranged that one man can control the entire electric output of the station. It is arranged in two tiers, divided into panels, one panel to each generating unit. An inspection of the illustration on page 203 of a portion of the gallery switchboard will enable the details to be better seen. In the upper portion of the figure, immediately in front of the incandescent lamps, are ammeters, or indicators of the current strength delivered by the various dynamos. A pointer moves in a vertical slot over sector scales. The position of this pointer can be read at a considerable distance.

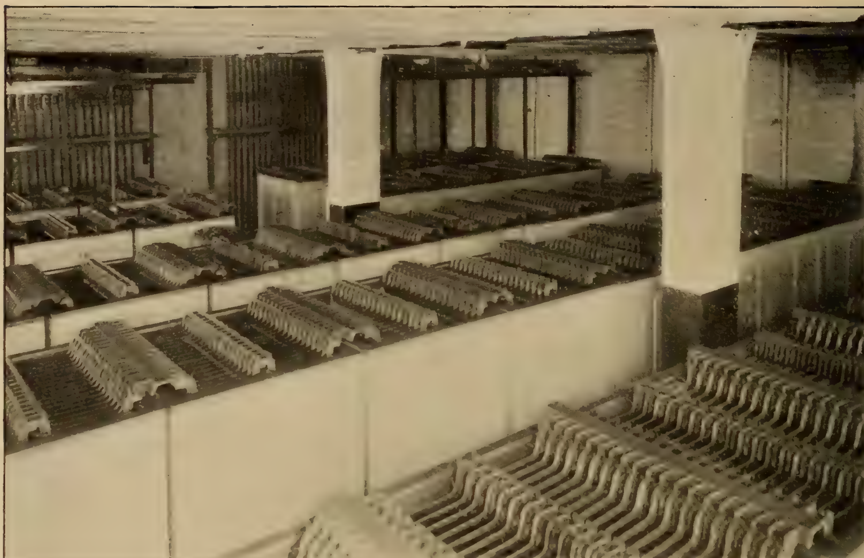
Immediately below each ammeter is a small pressure indicator to show

whether the pressure generated by the dynamo is equal to the main station pressure, before the switches are closed and the dynamo brought into action. Beneath the pressure indicator is a row of dynamo switches. There are four switch handles on each panel, two for the positive pole of one dynamo, and two for the negative pole. When the switch handles are horizontal, as is shown on the right-hand and left-hand panels, their dynamos are cut out from the circuit. When thrown up, as in the central panel, the dynamos are connected with the distributing system.

Below the dynamo switches is a line of vertical columns with cross bar handles. These are for controlling the pressure generated by each dynamo, and there are two on each panel. The position of the cross bars in their slots serves to indicate the pressure which



A SWITCHBOARD DETAIL.



THE STORAGE BATTERY PLANT IN THE BOSTON STATION.

is being employed from each generator. Thus, the central panel having its cross bars about midway up the range, indicates that the pressure of the generators connected with it is normal. To increase the pressure, by sending a stronger current through the dynamo field magnets, the cross bars are turned in a direction which makes them rise. To reduce the pressure, they are turned in a direction which lowers them. Some idea of the boiler plant required for such a station may be obtained from the illustration on page 198, representing a battery of boilers in the Chicago station.

Another example of the modern high type of central stations is shown in the illustration of the Boston Central Edison station on page 201. The interior view of this station shows four vertical compound engines, directly connected with multipolar dynamos.

We have already alluded to the fact that the load, which a central station has to supply through its underground mains, varies considerably with the time of day. It is evident that at night time, for example, the lighting load will be very heavy, and during the day-time it will be comparatively light. In a city like New York, the load during the day time is largely confined to the city districts, but during the evening, the load leaves the lower stations and develops upon the up-town or residence districts. It happens, consequently, that during the day-time, generating units are likely to lie idle until called upon to supply a heavy demand, or the peak of the load as it is called, which usually comes about 7 o'clock in the evening.

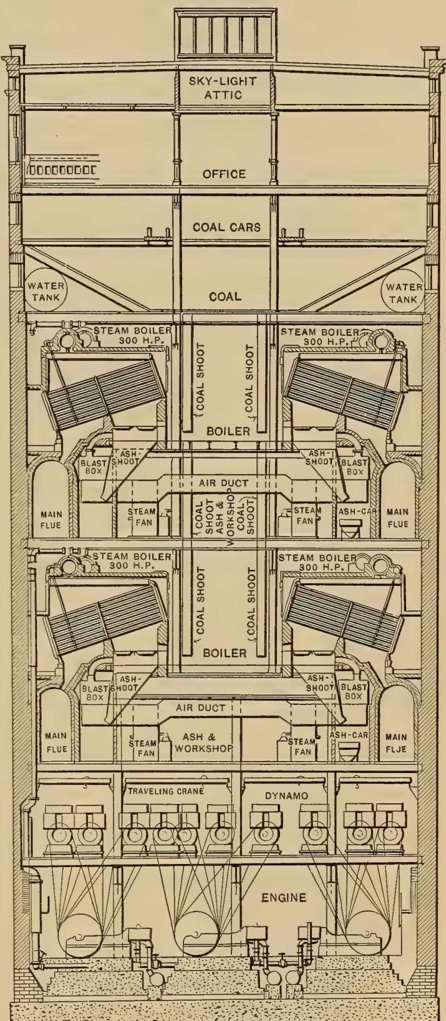
In order to reduce the large investment which is necessary to supply a demand lasting only a couple of hours a day, storage batteries have been introduced in some central stations. These are charged during the day-time, thus employing some of the idle units, and are discharged in the evening at the time of heaviest load, thereby reducing the number of generating units that would otherwise have to be installed. These batteries will supply 1500 ampères steadily, and, in case of need, 10,000 ampères for a few minutes without injury. An example of the use of storage batteries in central stations is seen in the illustration on this page representing a battery installed in the Boston

station. The disposition of the machinery in a central station is often a matter of considerable importance in its economical operation. Since the daily consumption of coal is considerable, means are provided for conveying it to the boilers with the least labour. An example of the means adopted for facilitating this operation is represented in the diagram on this page, which shows a cross section of the Edison station at Philadelphia. The coal storage is in the upper part of the building, to which the coal is raised by a special elevator. It is then lowered, as it is needed, to the floors immediately beneath where the boilers are located, and where the ashes are removed by cars running on a track. The steam is taken from the boilers to the engines in the basement, while belts connect the engines with the dynamos on the first floor.

The station shown is typical of good modern practice, and the disposition of the machinery and the general design of the building, for a given set of conditions, may be studied with interest and profit alike. The whole lay-out, as will be at once appreciated, tends towards a maximum of profitable utilisation of floor space, with all due regard to convenience and economy of operation.

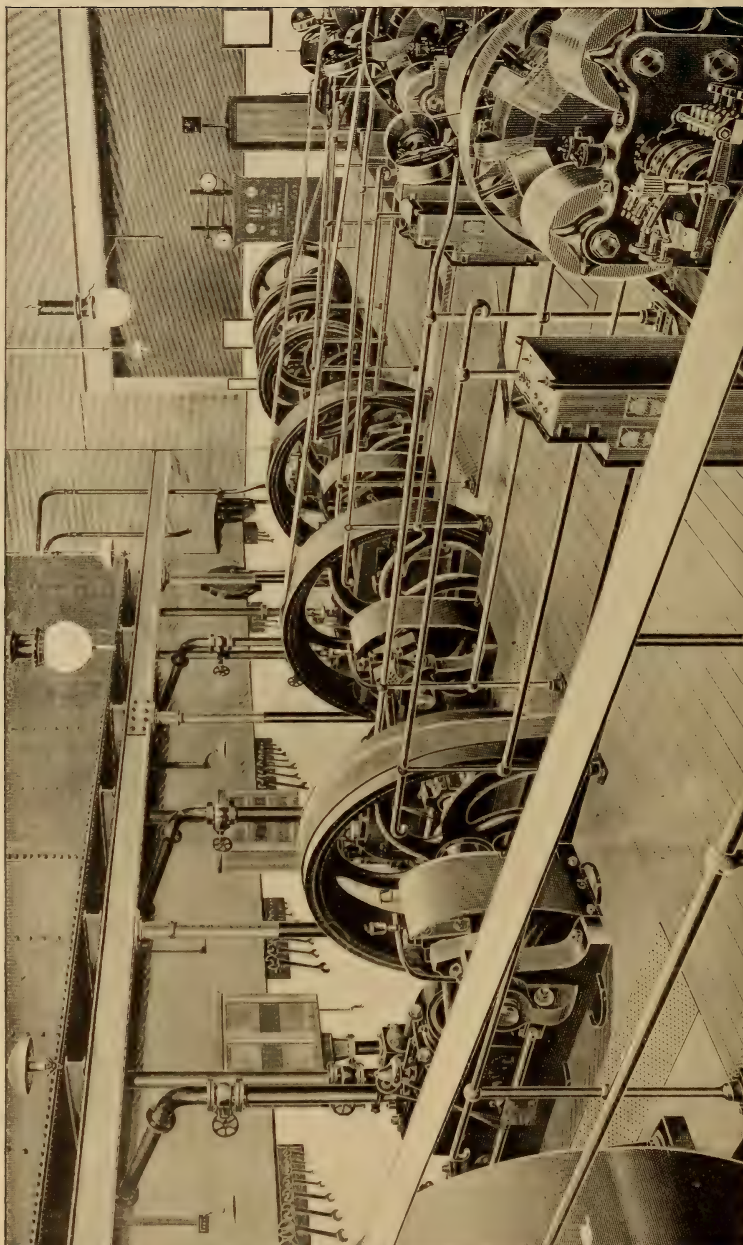
In the municipal distribution of light, heat and power, as it exists to-day, we meet with a wonderful series of transformations and transmissions. First we have the store of past solar energy in the coal. This is transformed into heat energy by combustion in the boiler furnaces. The heat energy is converted into the energy of steam in the boilers. This is next converted into mechanical energy by the engines, when it is again transformed into electric energy by the dynamos. As electric energy, it enters the buildings of the consumers, and is locally converted either into radiant energy in their lamps, into heat energy in their heaters, or into magnetic and then into mechanical energy in their motors.

It is the hope of the engineer and the dream of the poet that at no very distant date, some of these intermediate steps may be removed, and the process thereby simplified and cheapened, but all such Utopian ideas as have yet been formulated, have reference only to the



A CROSS SECTION OF THE PHILADELPHIA EDISON STATION.

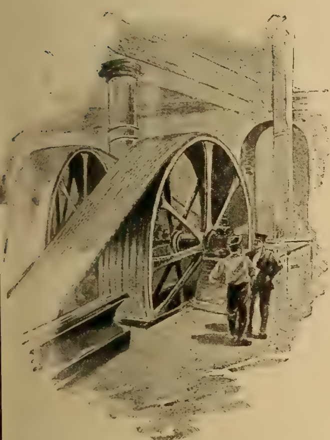
abridgement of processes taking place in the central station, and we must expect that even should such improvements be effected, the electric mains in our streets will continue to perform their present functions.



ELECTRIC LIGHTING PLANT WITH CROSSLEY GAS ENGINES AT THE LEICESTER STATION, MIDLAND RAILWAY, ENGLAND.

GAS ENGINES FOR ELECTRIC LIGHT AND POWER.

By Nelson W. Perry, E. M.



TAKING coal as the starting point, the maximum theoretical efficiency of the steam engine is 30 per cent., while the maximum theoretical efficiency of the gas engine is 80 per cent. All mechanical devices fall short of theoretical possibilities, and while the steam engine, through the intermediary of the boiler, might possibly give us 30 per cent. of the primal energy of the fuel, and the gas engine, 80 per cent., neither of them, even under the most favourable conditions, approaches these figures. The best that we can do under commercial conditions is to obtain in useful form, by means of the steam engine, about 10 per cent. of the energy of the coal, and with the gas engine, about 20 per cent.

The popular idea is that the price of fuel is controlling in the cost of power, but this is a fallacy that cannot be too rapidly dispelled for the best interests of the community. The cost of fuel, it is true, is an important item in the cost of power, and especially so where fuel is very dear, but it is often far less important than other items that are not usually considered by the layman, such as the interest on the original investment, depreciation, labour and others, and, above all, the relatively small proportion that we use of the total output of which the apparatus is capable. This is called the load factor.

If the apparatus be idle, the interest charges go on. If the engines are working at less than their full capacity, they are not doing justice to themselves, because the friction losses continue practically the same while the energy used is less. If, as often happens, it is necessary to throw out of use, for a few hours, a portion of the boiler plant, that portion is still costing something in the way of fuel, although contributing nothing to the income, and so and in other ways the 10 per cent. of the steam engine and the 20 per cent. of the gas engine are seldom realised in practice, while both are exceeded under test conditions.

The great problem of the day is how to work servants to the best advantage. The cheap cart horse probably covers more miles and does more useful work in a year than the high-priced trotter, but the former requires more food than the latter. This one may, notwithstanding the greater investment charges, net its owner more than will the cart horse. Neither could succeed in the domain of the other, but the cart horse is by far the more useful animal.

The gas engine may be likened to the cart horse, though this homely and to the gas engine, seemingly uncomplimentary simile is a very imperfect one. Some of the advantages of the gas using engine are :—

1.—It is, as made to-day, even in sizes as small as 10 H. P., quite as efficient as the largest compound condensing steam engine.

2.—It may be started at a moment's notice and stopped as quickly, consuming no energy while shut down.

3.—There are no water gauges nor safety valves to watch.

4.—In the case of gasoline and oil engines, there are no ashes to carry away, no chimney is required, nor, in

the case of small sizes, is the skill required to properly operate them by any means so high as that necessary with the steam engine.

5.—In the larger sizes of gas engines, where the consumption of gas is so large as to make it more economical to manufacture than to buy one's own gas, a gas generating apparatus is, in all respects, the equivalent of the boiler plant. The cost to install this is about the same or less per horse-power as the cost for the cheaper types of boilers. It is considerably less than for water tube boilers, the attendance is about the same or less, and the depreciation charges are far less than with steam boilers of any kind. This is a most important point.

The standby losses of a gas plant as compared with those of a boiler plant are about as 2 is to 10. Another point of vital importance is that the gas plant requires no chimney, so that in this economy there is another important item in the way of lessened original investment and consequently lessened fixed charges.

In case a small gas holder is used, the space required is no greater than with a steam plant, but the gas holder constitutes the cheapest and most efficient means of storage of energy known. It is this resource alone that enables gas lighting to exist as a commercial industry, and it will probably pay to make the holder a little larger so that this method of storage of energy may be available. By this means the standby losses of the gas generating plant may be entirely removed.

With steam, the only possible equivalent is the thermal storage of Druitt Halpin, which the author described in a paper before the National Electric Light Association of the United States a little less than a year ago. Halpin's method has a very considerable advantage over gas storage as regards space, requiring but 6.4 cubic feet per effective horse-power-hour storage, while illuminating gas requires about 20 cubic feet; but gas has at least equal advantage in the way of cost and other respects that will be referred to later.

In the way of fuel, the gas plant has the advantage in every way. With improved grate bars we are now successfully using such utterly waste products as the refuse from culm piles in the coal fields, but in the gas plant we can use this to still better advantage. By converting it into a fuel gas, we have a prepared fuel of a very high order,—superior in many ways to the very finest grades of steam coal anywhere to be found, and the same can be said of other refuse matters utterly incapable of being used under boilers.

Even with the best of fuels, the gas plant still has the advantage, for by its use 80 per cent. of the fuel is converted into gas and is brought to the engine, while it is scarcely possible to bring 70 per cent of the heat which coal should generate to the boiler. By no means all of this is utilised in either case, but a far greater proportion can be utilised in the gas engine than in the steam engine. This is the reason, or chief reason, of the truth of the statement made at the opening of this article, that "the maximum theoretical efficiency of the gas engine is 80 per cent., and that of the steam engine 30 per cent."

Sir Frederick Bramwell, at the Jubilee meeting of the British Association in 1881, made a prophecy which is likely to be fulfilled,—all except the museum part of it,—much earlier than the date set. He said that in 1931 engineers would look at steam engines of small size as articles of antiquarian interest, and that they would be put in museums, being out of use altogether, and superseded by internally fired engines.

It was Dr. John Hopkinson who first drew attention to the fact that when illuminating gas is burnt in a gas engine to drive a dynamo, much more light is produced if incandescent lamps are used than can be produced by burning the same quantity of gas in burners in the usual way. Such a statement seems anomalous, but it is not only true that more light can thus be gotten, but that one can buy city gas at ordinary rates, burn it in a gas engine and light his house with electricity more

Nelson W Perry

NELSON W. PERRY is a Harvard University and Columbia College graduate and, for several years past, has devoted himself particularly to electrical pursuits, having, in that time, established for himself a prominent position in the electrical profession.

cheaply than he can with that same gas direct or with electricity bought from any of the electric light companies at their usual meter rates. This the writer found, by tests, was actually being done in several places.

If the private consumer can do this after having paid a profit for his gas to the gas company and for the cost of delivery, the question arises, why cannot an electric light company do the same? If city gas were used to drive the dynamos of a central station, the consumption would be 50 per cent. less than the volume required to give the same number of lights as the dynamos thus driven could furnish at the station. In other words, if a central station drove its dynamos with city gas, those dynamos would supply just twice as many lights as the gas thus used could supply directly in gas burners.

The electric light station could throw away or sell its boilers and engines and devote the boiler plant space to other uses.

There would be no expense for firemen nor for the removal of ashes. Coal would not have to be handled and the saving in coal bills and in the space necessary for coal storage would lessen the gas bills by so much. Furthermore, there would be no stand-by losses as at present, and instead of keeping up steam in order to meet any sudden fluctuation in the load, the standby would be the gas main, requiring only to be tapped to supply any demand.

Of course, nothing of this kind is practicable, for the simple reason that no gas company is going to shoulder all the disagreeable features of its rival's business in order to enable the rival to compete with it. But as a simple proposition, there is no question that if a lighting station could buy its fuel from the gas company it could pay the latter its usual rates and still beat it on the ledger.

Would it pay, then, for an electric lighting company to establish an illuminating gas plant for its own supply? Probably not, for the reason that unless everything were on a very large scale the economies in space and labour above referred to would not only disappear, but, instead of economies, greater charges on these accounts than before existed would undoubtedly result.

Another question here suggests itself. Supposing a single corporation owned a number of large lighting stations, distributed in different portions of a city, having enough customers combined to make, if these customers used gas, a gas plant a paying investment, would it pay that corporation to erect a central gas plant, and from this distribute illuminating gas solely to its various stations for use with gas engines, assuming also the right of way for its pipes could be obtained? I think it would.

In the first place, it has been found profitable in many places to distribute electricity at high potentials from a central lighting station to a number of sub-stations for the purpose of charging accumulators at those sub-stations. But it is cheaper to transmit gas than it is to transmit electricity on low potential circuits. Mr. Denny Lane, an English engineer of prominence, says that with ordinary 16 candle-power gas, 3000 H. P. could be sent a distance of one mile for an expenditure of one horse-power,—an economy of distribution far exceeding that possessed by any other system, being only $\frac{1}{30}$ per cent. of the power conveyed.

With respect to the cost of mains, taking the cost of conductors laid on the low-pressure culvert system at £5500 per mile for the conveyance of 1080 ampères, and assuming an electro-motive force of 110 volts, the power would be 158 H. P. It would, therefore, require, he says, two pairs of these conductors to convey 300 H. P., whilst a 6-inch main, with ordinary gas, would convey sufficient gas for that power at 4 inches pressure, and at 16 inches pressure would deliver as much as four pairs of such conductors. The 6-inch main, he says further, would cost £500 per mile, while two pairs of low-pressure conductors would cost £11,000, and four pairs would involve an expenditure of £22,000 per mile.

The writer has found, by calculation,

that to transmit this power to the distance named at 220 volts, the metal in the pipes would cost considerably less than the metal in the conductors. Contrast this with electrical transmission, in which 10 per cent. or 300 H. P. would be an allowable loss, and we see how the gas transmission has the advantage over the electrical.

The ideal location for an electric light plant is in the centre of the district to be supplied. It is not often that such a location is favourably located as regards fuel, and the latter has to be carted from the railroad, which involves a double handling and an additional charge on the fuel. In such a location real estate is apt to be high, and economy of space, therefore, becomes particularly desirable, not only to save taxes, but to reduce the investment account, so that the interest charges may be reduced to a minimum.

Could we abolish the boiler from such a location, the saving in real estate would be about two-thirds. If we employed gas, the gas plant might be placed on the railroad or at tide water, where land was cheap and where fuel could be delivered at a minimum cost. The gas generated there could be transmitted with insignificant loss to the lighting station where the gas engines and dynamos, arranged upon a minimum of real estate, but upon the several floors of a building, would work under conditions of fixed charges far more favourable than usually exist. Further than this, an inferior, and therefore a cheaper, grade of fuel would be permissable.

Thus far we have, in speaking of gas, referred to illuminating gas. But the near future is to see the general introduction of a cheaper grade of gas, intended solely for fuel purposes. This fuel gas, already largely used in some metallurgical operations, and in isolated plants with gas engines, is essentially a water gas, but of lower grade than that produced in illuminating gas establishments, and is still further cheapened by the omission of some of the cleansing processes necessary in the latter. Its specific gravity is 0.87 to 0.88 and its calorific power, as compared with 16-candle-power illuminating gas, is about one-fourth. The cost to produce it in England is between 2d. and 3d. per 1000 cubic feet.

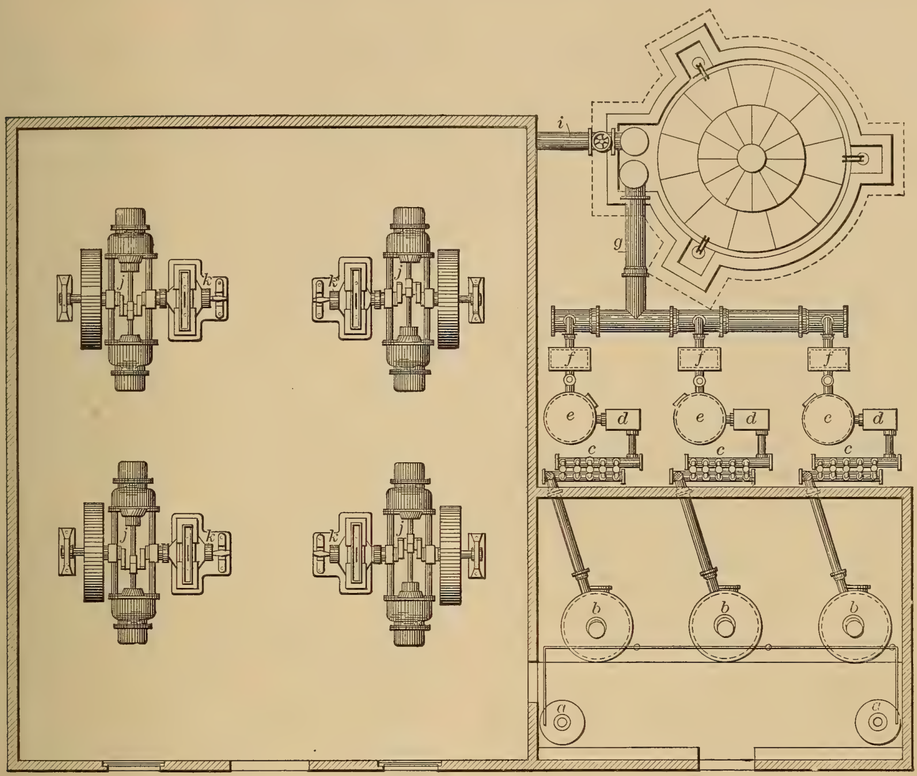
The process of manufacture is exceedingly simple, and consists in forcing steam and air into a sealed ashpit, above which is an anthracite or coke fire. From the generator the gas passes first through a cooler, then through a coke scrubber, and then through a sawdust scrubber, whence it passes to the gas holder. One ton of fair anthracite coal will produce from 150,000 to 160,000 cubic feet of this gas, and in its use the following economies are usual :—

At Chelsea, England, Messrs. Mead & Son have a 60 H. P. (nominal) Crossley gas engine with twin cylinders, employed in driving a flour mill. While the engine was still new (3 months' service), a trial, lasting 8 hours, was made by Mr. Dowson with the millwork going on in the usual way. This test was confirmed by a second day's run, and gave the following results :—

	Left Cylinder.	Right Cylinder.	Both Cylinders.
Mean pressures of indicator diagrams in lbs. per sq. in.	79.9	77.9	78.9
Average I. H. P. during trial, with speed of about 156 revolutions per minute ...	59.3	59.4	118.7
Maximum I. H. P. with full speed of 160 revolutions...	----	----	173.6

Anthracite consumed in the generator during trial	0.615 lb.	per I. H. P.	per hour.
Coke consumed in boiler during trial ..	0.147 "	"	"
Total during trial.	0.762 lb.	per I. H. P.	per hour.
Anthracite put in the generator on the morning after trial, to make up for loss during nine night hours, 56 lbs.........	0.058 lb.	per I. H. P.	per hour.
Ditto to make up for loss when raking out clinkers, etc., 50 lbs.	0.053 "	"	"
Total loss during the night, and after clinkering on the following morning, 106 lbs	0.111 "	"	"
Water for cooling the engine	5 gallons	"	"
Water for boiler of gas plant	½ pint	"	"
Water for washing gas, etc	1 pint	"	"

It will be noticed that the standby losses of the gas generator were exceed-



PLAN OF A CENTRAL STATION WITH GAS PLANT AND ENGINES FOR 400 KILOWATTS.

ingly small in this case. As this question is one of considerable importance, it may be worth while to recount some other experiments in which these losses were very carefully determined.

In discussing a paper by Mr. Dowson on "Gas-power for Electric Lighting," read before the British Institution of Civil Engineers, in 1893, Mr. Dowson said that in order the better to determine these losses he had resorted to the expedient of placing the generator on a weighing machine. The gas was taken to an engine under trial, and by having a hydraulic joint, perfectly free in the pipe leading from the generator, gas was made continuously, while, at the same time, it was possible to tell at any time what was the actual weight of fuel converted into gas. The generator was worked with anthracite, and served about 32 brake horse-power. After the trial, the generator was left on the weighing machine, with a fire in it, but without draught, for 18 hours, in the month of November, and during that time the waste of coal was 18 lbs.

On another occasion, a generator of about the same size had been worked in a similar way with coke, and, after the trial, was left on the weighing machine in the open air, in November, for 17 hours. During that time the waste of coke was 60 lbs., or about 3½ lbs. per hour. On still another occasion, at Chelsea, a generator served about 150 I. H. P., and three tests had shown that the waste of anthracite during the time of standing was from 6 to 8 lbs. per hour. At Openshaw a still larger generator worked with anthracite, and, serving between 250 and 300 I. H. P., was worked under the following conditions:—

On the 19th inst., the working of the generator was stopped at 8 P. M., and started again at 5 A. M. the next day. The waste during these 9 hours

was 69 lbs., or 7.6 lbs. per hour. On the 20th inst. the generator was stopped at 8 P. M. and started again at 5 A. M. the next day, the waste being 5.1 lbs. per hour. On the 21st inst. the generator was stopped at 2 P. M. and started again at 7 A. M. on the 23d inst.,—an interval of 41 hours,—the waste being 3.9 lbs. per hour.

It is very evident from these figures that the standby losses of a gas generator are almost negligible as compared with what would occur with steam boilers, and that, thus, one of the greatest sources of fuel loss in the central station may be obviated. Just what the standby losses of steam boilers are, it is difficult to state with any degree of accuracy, but Prof. Kennedy and Mr. Crompton both estimate it at about 10 per cent. of the total consumption in all the boilers, or, for every 1000 tons utilised, 100 would be charged to standby losses.

Let us next take up the gas engine. The losses between a gas generator and engine will be less than between a boiler and steam engine, first because in the former there is no condensation and second because the gas, being under, at most, one or two inches of water pressure, the leakage due to defective joints would be small, whereas with steam under high pressure it might be large.

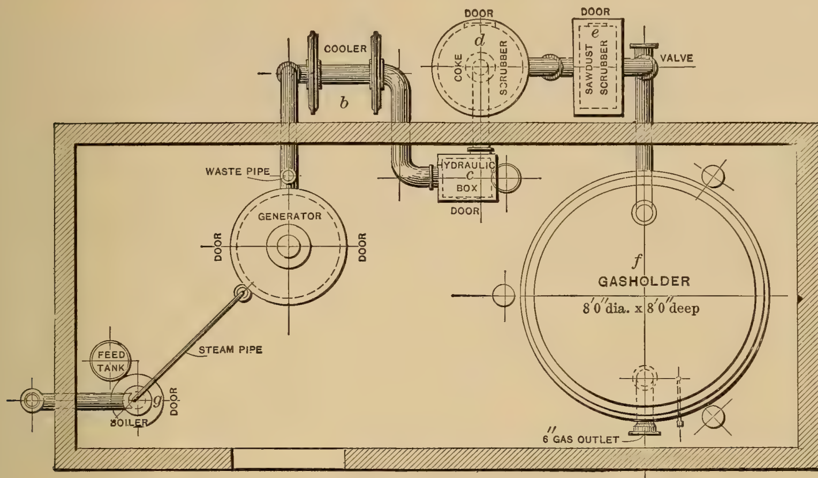
As regards the mechanical efficiency of the gas engine, Mr. Bryan Donkin in his "Gas, Oil and Air Engines," tabulates the results of a very large number of tests with engines of different makes and sizes, which show efficiencies varying between 55 and 91 per cent. Most of these were very small engines,—less than 10 H. P., and some as small as 1 H. P., the largest, except one, being 27.75 brake H. P., which gave 82 per cent. The one exception was working at 92.5 brake H. P., and gave an efficiency of 72 per cent. These figures seem low, but will compare favourably, except in the last instance, with efficiencies obtained from similar sized steam engines.

It has been argued that the use of gas engines necessarily involves the use of small electrical units. This is not strictly true, however, since it is customary, where larger units are desired, to couple up two or more engines to one generator. By so arranging these engines as to have their explosions alternate with each other in the case of a pair, or to succeed one another in case of a larger number, a positive advantage may result in the way of greater regularity of speed. While, so far as the writer knows, the largest single gas engine thus far built is of a capacity of 375 H. P., compound gas engines of considerably greater capacity have already been built, and it is understood that the leading English manufacturers stand ready to fill orders for compound engines up to 1000 H. P. if desired.

The demand for the larger sizes of steam engines is chiefly due to the fact that in them greater efficiencies are attained than with smaller ones. This is not true with gas engines, however, —at least not to the same extent. With dynamos, after a certain size is reached, no further increase in efficiency is possible by still further increasing the size, so that the reason for large units does not exist in the dynamo. With varying loadlines, such as we have in lighting stations, large units are, in one sense, a positive disadvantage, in that they can meet the variations less efficiently than could smaller ones. With the gas engine, therefore, in which, in the smaller (as compared with steam engines) sizes, equally high efficiencies are attainable, and where, when shut down, the consumption of fuel absolutely ceases, the reason for large units, to a certain extent, disappear.

For an electric plant of 400 K. W., Mr. Dowson* recommended the arrangement shown on page 213. In this there are three generators, each capable of supplying one-third of the maximum power. Each generator has its own cooler, hydraulic box and scrubbers, so that they can be worked together or singly. The cost of this plant, including erection, foundations and ashpits for

* "Gas Power for Electric Lighting" by J. Emerson Dowson in a paper before the British Institution of Civil Engineers, Jan., 1893.

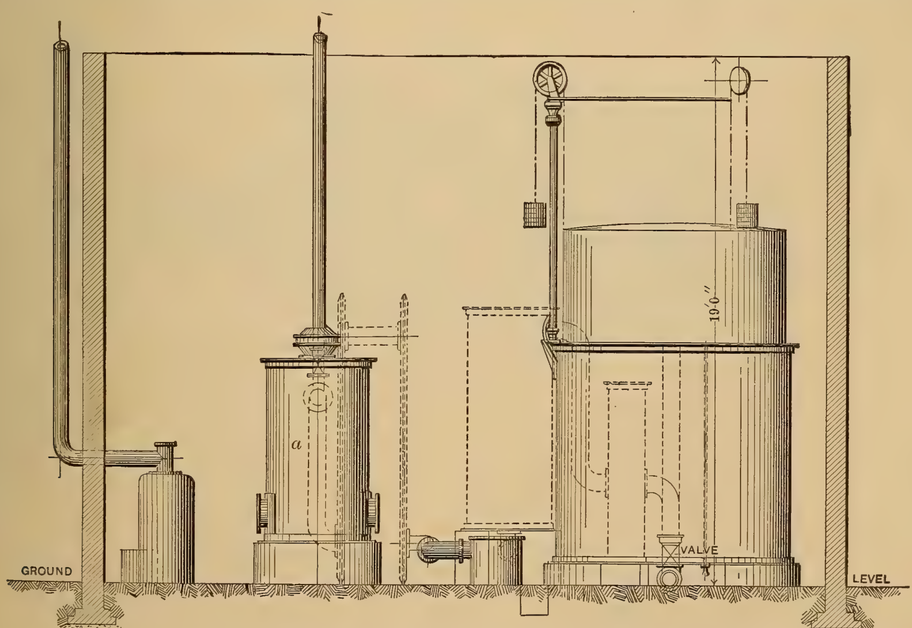


PLAN OF A 100 HORSE-POWER DOWSON GAS GENERATOR PLANT.

generators, is given at £1100 or about £2 per H. P. for the gas plant. If this were all on one level, it would occupy a ground area of about 27 feet by 54 feet; but, if necessary, he states that all, except the gas holder, can be placed under or over the engine room.

On this page are a plan and an elevation of a Dowson gas generating plant of 100 H. P. kindly prepared for the writer by Mr. Dowson himself. This shows, in detail, the arrangement of the various parts making up a single unit of 100 H. P. A larger plant would consist simply in a multiplication of such units as are shown in plan on page 213.

Mr. Thwaite in England has suggested the conversion of coal at the coal



ELEVATION OF A DOWSON GAS PLANT.

mines into fuel gas and the utilisation of this gas in gas engines for the production of electricity, to be transmitted to neighbouring towns for light and power purposes. In the anthracite coal regions in the United States there are vast accumulations of culm of which the fuel value is already attracting attention. As burned under boilers, there is much waste,—sometimes as much as 30 to 40 per cent. of the fuel being found unburnt in the ashpit. A much more rational procedure would be to convert this into a first-class and manageable fuel in the form of fuel gas, and then burn it in gas engines for electrical and other purposes.

If this culm could be laid down on the water front in New York or Philadelphia, as has been claimed, at $1.85 per long ton, and there converted into fuel gas, it would be possible, if the right of way could be procured, to pipe it to every electric light station in either city, where, if gas engines were employed, it could be directly converted into electricity at a cost far less than at present attends the production of electrical energy.

It may be too soon to expect such revolutionary methods, and probably it is, but metallurgists have long realised that the ideal fuel is a gaseous one, and are awaiting its coming into general use with some impatience. The advent of natural gas has educated the public to its use and the appliances for its proper utilisation are all existent. It remains only for some enterprising individuals to start a fuel gas plant for public supply just as illuminating gas plants exist for gas lighting supply. When such an organisation comes into existence, the public will be the gainers, and among that public none will be a larger beneficiary than the electric light manufacturer.

Chas. E. Emery

DR. CHARLES EDWARD EMERY is one of America's foremost engineers. One of his best known achievements was the design and construction, in New York, of an underground steam system which successfully solved the problem of supplying high-pressure steam for heat and power purposes from central stations through street mains.

WATER POWER AT FOLSOM, CAL., U. S. A.

WHEN IT IS ADVANTAGEOUS TO USE WATER POWER AND ELECTRIC TRANSMISSION.

By Charles E. Emery, Ph. D.

IT should be advantageous to use water power when it is cheaper than any other source of power and equally reliable. The cost, however, depends largely on the question of availability. All comparisons are naturally made with steam power, which can be furnished in any location, in any desired quantity, at a cost fixed by the particular conditions. The water power may not be in the location where power is desired; the quantity of power required may not be sufficient to warrant the development of the water power by a single manufacturer, and there may not be sufficient demand for power in the particular location to warrant the development by a special company. When, however, such development has been made, a new set of conditions is set up.

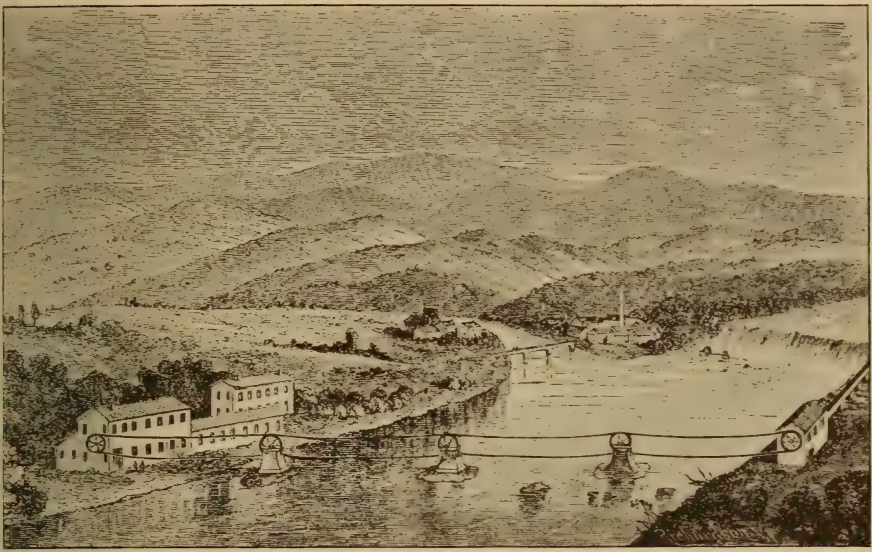
The water power can then be sold, at the site, in quantities small or large, like any other commodity, and, moreover, the later developments in electricity have made practicable the transmission of power to a distance where it can be utilised in large or small units. Under such circumstances, the transmitted power is brought in competition with steam power, either as a substitute for established steam plants, or as the original source of supply for new enterprises.

In order to make it commercially desirable to develop a water power there must exist, first, a demand for power in considerable quantities; second, an available water power within a reasonable distance of the centre of demand; and, third, economic conditions which will enable the power, when transmitted, to compete with steam engines where the power is required.

When steam power is already used at a large number of locations, the water power to supplant it, must be supplied to the shafting already revolved by the steam engines. New consumers will be supplied by electric motors direct; the electric light stations, by

electric motors turning shafting already in place, if the electric current transmitted is of a different kind than that demanded; but, in general, the alternating current, used in the transmission, will be transformed down in potential and transmitted to consumers for lighting purposes, in lieu of that furnished by the electric generators in place in the local station, and, for that portion of the load, transformers will take the place of the engines and gen-

THE FIRST ELECTRIC LONG-DISTANCE TRANSMISSION, AT THE MUNICH ELECTRICAL EXHIBITION, 1882, CONNECTING MIESBACH AND MUNICH, GERMANY, 37 MILES APART.



TRANSMITTING WATER POWER FIFTY YEARS AGO.
FROM AN OLD ENGRAVING.

erators. In some cases, however, so many direct-current motors may already have been installed, that it will be desirable to continue the supply of current to them, when, in some instances, electric motors will be used instead of the engines to operate dynamos already installed. In other cases, rotary transformers will be employed to convert the alternating current transmitted into direct current.

Polyphase alternating currents are now universally employed for the transmission of power, so that in all new installations such currents will be transmitted over the entire area and used both for lighting and power purposes without being converted into direct current, and cases will occur where it will be advantageous to throw out direct-current appliances and substitute those for polyphase alternating currents on account of the more general adaptation of the system.

The development of a water power for the purposes suggested requires the expenditure of a large amount of capital. The stream must be dammed in some cases, wheel-pits, head and tail races must be constructed in any event, and means of transmission supplied to convey the power wherever desired. Mechanical means of transmission are limited to comparatively short distances. The electric transmission is, however, available not only for long distances, but late investigations show that it is cheaper, in many cases, for the short ones where mechanical means are practicable. It is conceded that the proper way to transform the hydraulic into electrical energy is to construct what may be called "turbine dynamos," each consisting of a turbine driving a dynamo directly, and to mass a number of them at a convenient location and transmit all the power from there electrically.

When a water plant is once completed, the chief items of cost are interest and maintenance. There is no continuous outlay to be made for a source of energy like that required for coal, with a steam engine. The cost of maintenance, when the work is once well constructed, should, as far as the features for utilising the water power are concerned, be relatively small. The electrical apparatus is comparatively

PENSTOCKS AND TURBINES AT THE FOLSOM, CAL., POWER STATION.

simple and should not involve extraordinary maintenance expenditures. The interest on the capital invested is the predominating element of cost, and before any comparison can be made, it is necessary to ascertain what money is worth at that particular location.

In ordinary mercantile transactions, the investor wishes something more than simple interest on his investment, as that can be secured by real estate and bond investments, involving little or no risk. Until such enterprises are well established, so that the structures show themselves to be substantial, and the enterprise pays a fixed income, it cannot be expected to borrow money at less than the regular rate of interest, and if the work is to be done largely with borrowed money, then the net income must be sufficient to pay the interest on that, plus a dividend to the shareholders ; so, while the private investor requires more than the regular rate of interest to cause him to undertake such an enterprise, the speculator

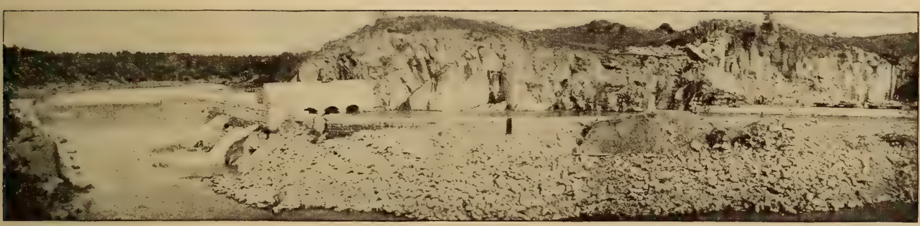
also requires more, considering interest and dividends together. Few people would invest in such an undertaking unless it was expected to receive more than 10 per cent. interest, and such a rate would not warrant the large issues of stocks and bonds generally incident to corporate work. A charge of 10 per cent. for interest and dividends will, however, be used for comparison.

Before proceeding farther, it will be of interest to ascertain the average cost of steam power. It is generally asked: What is it worth per horse-power? Technically, this question cannot be answered. Horse-power is a mere rate of work. It is equivalent to the raising of a weight of 550 pounds one foot high in one second, or 550 foot-pounds per second, or, more strictly, equals the work required to move a resistance of 550 pounds through a distance of one foot in one second. This is equivalent to 33,000 foot-pounds per minute and is proportioned to the time of operation.

One horse-power continued one hour called a "horse-power-hour," is a unit of work and means simply 1,980,000 foot-pounds of work without any reference to time. Similarly, a rate of work corresponding to one horse-power, continued during certain hours of a year, is a quantity measurable in foot-pounds, but varies with the number of hours of operation.

In calculating the value of a horse-power per year of steam power, we have first to assume a certain kind of steam engine, a certain steam pressure, and a certain grade of steam machinery, and for these conditions we know by experiment the quantity of coal that will be consumed in the boilers to develop the power required. In some cases, power is used only in working hours, or, say, 3090 hours per year. In other cases, more or less power is required out of working hours, on nights and holidays, for instance, and in exceptional cases power is steadily required the whole 8760 hours of an ordinary year. The horse-power-year may, therefore, contain several times as many hours in some cases as in others, and the cost will vary accordingly.

The horse-power-hour is, however, a definite unit of work, and can be used as the basis of measurement for the most fluctuating power. Even fluctuations taking place in less than an hour can, by ascertaining the average foot-pounds of work done for that period, be reduced to horse-power-hours, and while it is equally true that variable work could be expressed in horse-power-years, this should not be done except for similar kinds of work for which the number of hours of operation is understood.



THE FOLSOM WATER POWER COMPANY'S DAM AND CANAL.

The cost per horse-power for steam power, developed in a good compound engine of over 100 H. P. maximum capacity, for, say, 10 hours a day for 309 working days in the year, with coal at $3 (12 sh.) per ton is, including approximate taxes, insurance, cost of renewals and 10 per cent. for interest and dividends, about $25.53 per year (£5 2sh.), or about 8¼ mills ($0.00826) (0.4d.) per horse-power-hour. If the operation were continued every hour in the year with other conditions as

above mentioned the cost would be about \$48 (£9 12sh.) per H. P. per year or only 5½ mills (\$0.0055) (0.264d.) per horse-power-hour.

The cost of steam power may be reduced somewhat by the use of triple-compound engines and greater care in operation, but the figures given are believed to be what may fairly be obtained under practical conditions with good compound engines under good business management. Of course, the cost will be reduced materially where coal is cheaper than \$3 (12 sh.) a ton. The cost of the power increases rapidly to about \$75 (£15) per horse-power per year of 3090 hours, or 2.42 cents (1.16d.) per horse-power-hour, as the size of the engine is decreased to, say, 20 H. P., when the cost of labour and the type of engine that would probably be employed are considered. For less than 20 H. P., the engineer may, in many cases, have other duties, so that the increase of cost for decrease in power will be less rapid.

In portions of a city containing small manufactories, the power would generally be required only during working hours, and though there would be a comparatively small number of large engines, they would have a predominating influence on the total horse-power-hours, so that it is probable that not more than one cent per horse-power-hour, or \$30.90 (£6 3s. 7½d.) for a year of 3090 hours, could be obtained on the average. In business districts where small powers are required at irregular intervals, or even moderately high powers for very short intervals, as in running elevators, a much higher price can be obtained according to the experience of the electric light companies.

The lowest price obtained for this service, known to the writer, is 5 cents (2½d.) per horse-power-hour, but the total number of horse-power-hours thus secured is small compared to those required for regular manufacturing purposes. Again, in order to obtain large blocks of power on a 10-hour basis, it would evidently be necessary to reduce the price well below one cent (½d.(per horse-power-hour.

The power required in electric lighting and electric railroad power stations is very variable. The momentary fluctuations are greatest for the railroad work, but the variations from the average are as large in electric lighting plants, though the changes are less sudden. In a business district, lighting circuits have a fair load during business hours, to light dark rooms and to run motors, and in case of a storm the load suddenly runs up, but drops off as quickly. In winter, it rises quickly at dusk and is of comparatively short duration, while at night very little is done. In residence districts the load is quite low, except between dusk and midnight.

The percentage, that the average power used during the 24 hours bears to the maximum, is called the "power factor," and though this is usually as low as 35 to 40 per cent., it generally insures about as many horse-power hours, during 24 hours, as would be obtained by operating the maximum power for 10 hours a day in regular manufacturing work. The consequence is that the cost of the power, when the variations are no greater than stated, is not very much larger than for more regular power operated 10 hours a day, the extra cost being simply due to the fact that the labour cannot be distributed, during each hour of the twenty-four, exactly in accordance with the amount of power developed, and it is necessary in all cases to have surplus labour, as the variations evidently cannot be absolutely the same on different days.

It follows, therefore, that if the cost of variable power be expressed in terms of the maximum power, it will, under conditions stated, not vary greatly from that stated on a 10-hour basis, or say \$26 (£5 4sh.) per H. P. per year, whereas, if the cost be expressed in terms of the average power, the apparent cost rises to nearly \$75 (£15) per H. P. per year. The cost per horse-power-hour will, however, be the same in both cases, or about 8.4 mills

(0.4d.) and this is the basis which must be considered in fixing prices.

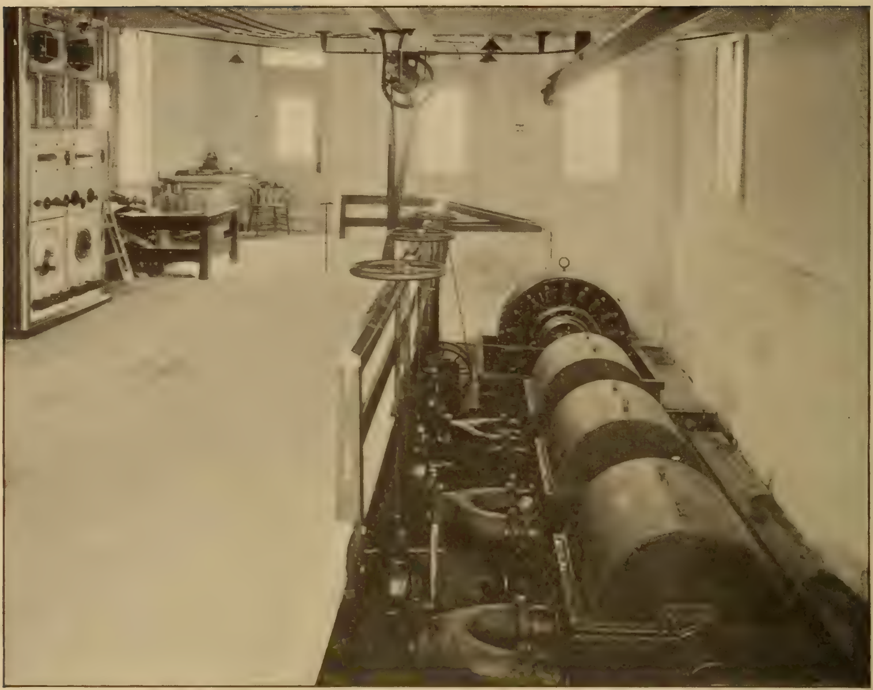
In determining the corresponding cost of water power, we will, for simplicity, assume that the interests of the intermediate party selling electric power and of the company developing the water power, are identical, so that the cost of the two operations may be summed together, it being evident that the cost will be increased if the work is conducted by two separate companies. Water power can be made available for use in a particular location at a low price, first, when very large quantities of water power are provided for in the first instance; and, second, where there are special advantages in the location of the power, so that the costs per horse-power become very low.

The costs of installing a water power vary so greatly that it is common, in general comparisons, to assume that such cost is about the same as that of installing a steam plant, or $50 to $75 (£10 to £15) per H. P. utilised. Large water power developments can be made at a lower price per horse-power and, in order to establish approximate comparative conditions, we will assume that the cost of developing such a water power and of supplying turbine-dynamos, ready to deliver electric current at the site of the fall will be the same as that of developing an ordinary water power with local mechanical means of transmission.

If, then, the hydraulic and local electric plants cost, say, $50 (£10) per H. P., we should add as much more for the electric transmission, which necessarily includes all the apparatus and the ramified conductors necessary to deliver the power to the very large number of consumers who are to utilise it. The total assumed cost will then be $100 (£20) per H. P. and the yearly charge for interest will be $10 (£2) per H. P. It will not be safe to assume a less proportion for renewals, interest and insurance than in the case of steam engines or 5 per cent. = $5 (£1) per H. P., and the labour and supplies required for operating and keeping in ordinary repair the turbine-dynamos, transmission lines and motors and transforming apparatus, used on the premises of the consumers, cannot be less than $5 (£1) per H. P. per year, making the total price for which a large company under such conditions can sell water power to consumers, $20 (£4) per H. P. per year on the basis of receiving 10 per cent. on the capital for interest and dividends. If, therefore, the first cost and cost of operation, based on coal at $3.00 (12 sh.) per ton, can be kept down to the figures named, electric power, derived from water power, can be sold to various consumers at a price which will afford them a saving in cost and, at the same time, a profit to the hydraulic company.

The advantages are not, however, as great as have been expected. Manufacturers have unreasonably expected that they would obtain the power for half of what it was costing with a steam engine, and supposed that such cost was even lower than stated above, whereas the fact is that it is generally greater, because few establishments have given careful attention to the subject of economy of fuel. On the contrary, the fact that manufacturers generally underestimate their cost, together with a knowledge of the high prices received for very small quantities of electric power by the electric lighting companies, have established a belief by the power companies that much higher prices than those named can be obtained for water power distributed by electricity.

One prominent company, for instance, has offered power at the terminals of turbine-dynamos for $18 (£3. 12sh.) per H. P. per year, whereas we have calculated that they should be able to deliver it for $20 (£4) to consumers many miles distant, and as one-half of the latter cost is made up of items incident to the transmission, about $10 (£2) should be added to the $18 (£3. 12sh.) offered, making $28 (£5. 12sh.) per H. P. per year as the cost for which power would, on the average, be delivered to consumers under the most favourable circum-



PELTON WATER WHEELS IN THE ELECTRIC POWER PLANT OF THE SIMONDS SAW WORKS, NEAR FITCHBURG, MASS., U. S. A. LENGTH OF TRANSMISSION, 3 MILES.

stances, which price would be an advantage to those using small powers, but not to those developing large power with economical steam machinery.

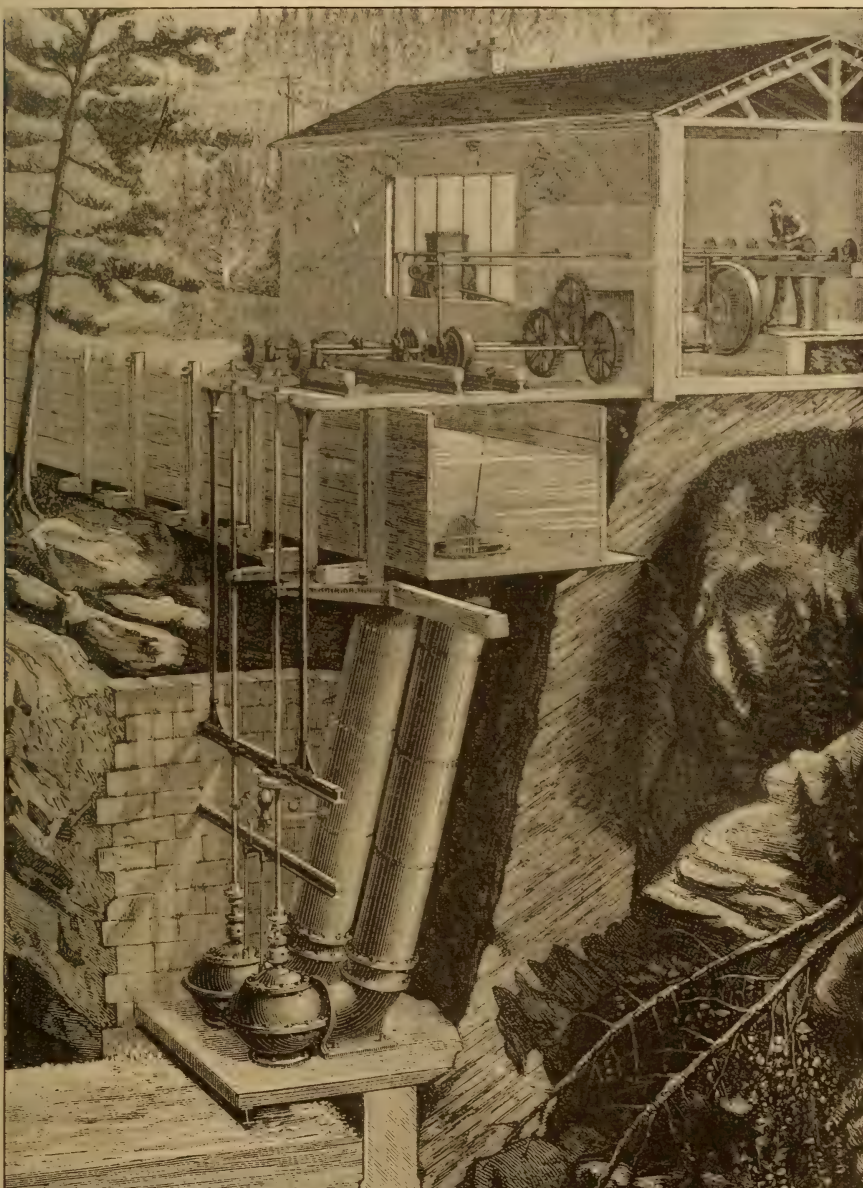
It should be borne in mind that as respects the cost of water power, the estimate is only approximate. No accurate estimate can be made unless it is applied to the circumstances of a particular case and based on the actual cost of the development of water power, the actual cost of transmission and the actual cost of attendance. It is believed, though, that in some locations the cost at which water power can be furnished to consumers will be higher than has been considered. Naturally, the transmission would be undertaken by a company other than the hydraulic company, which, of itself, would involve a new capitalisation on customary inflated methods, a new organisation and an intermediate profit which would very considerably increase the cost. Moreover, the present estimate has been made on the basis of coal at $3 (12sh.) per ton, whereas it can be obtained at one-half that price, or a little more, along the lines of great water communications.

It will naturally be argued that the costs of installing motors and caring for them and the electric apparatus in connection therewith, should be borne by the consumer, as the same takes the place of steam machinery. All the new apparatus is, however, extra to parties already having steam plants. Moreover, we have charged against the estimated cost of steam power 10 per cent. on the cost of the plant and all the items of labour, renewals, insurance, etc., which have been included in connection with the electric plant. It follows, therefore, that if the consumer pays any of these charges, he must have a corresponding reduction in the cost of the transmitted power.

The general result of the above investigations is, then, that it will be very

difficult for electric power, transmitted from a waterfall, to compete with steam power, for ordinary manufacturing purposes, in locations where coal is cheap, say less than $3 (12sh.) per ton. The contrary is the case where power is required uniformly during 24 hours a day, or in locations where coal is high-priced, whether the plants are operated during working hours or for longer daily periods.

The comparisons above made, it will be observed, are either for working hours or for variable power developing



THE WATER POWER OF THE PORTRUSH ELECTRIC RAILROAD IN IRELAND, 1883.

about the same number of horse-power-hours as for regular working hours. Water generally flows during the whole twenty-four hours, and it is understood that the power is available for that time at the same price per year as for use during a less number of hours. The cost of steam power increases with the number of hours, so that, if water power can compete for 10-hour power, it will be very cheap for power continued nearly uniform for twenty-four hours.

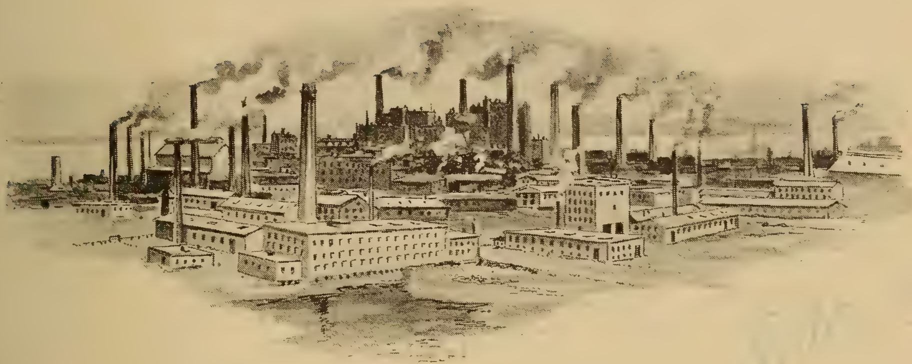
Again, there are many locations off the main lines of transportation, or distant from the coal fields, where the price of coal is very high. In such location water powers for electric transmission are being rapidly established and the investments cannot but be remunerative.

Again, it should be stated that it will be advantageous to establish a water power and electric transmission for lighting purposes under conditions that would not pay for power purposes. For lighting, the electricity, once generated, is used directly, the alternating current being merely transformed down to a potential which is safe to distribute to consumers. When the electric current is used for power, another transformation, through revolving mechanism, is necessary, which not only increases the cost on account of losses in transformation, which may not, of themselves, be very serious, but add largely to the cost of the plant, so that the interest charges are increased. Again, the cost of attendance is increased. The two items last named are incidental to the use of steam power, but, in the estimates above, have been already charged and must, therefore, also be charged to the electric transmission.

It is economical in very many places to supply electrical current from water-falls at a distance, even under present conditions, as is shown by a considerable number of installations that are being made. The more work that is done of this character, the cheaper similar undertakings can be carried out, so that the business is bound to continually increase with benefit both to the promoter and the consumer. Every case must, however, be considered on its merits, and the object of the present paper is not to discourage developments, but, on the contrary, to call attention to the limitations, so that no such enterprise will be undertaken without a reasonable certainty that it will be profitable to the original investors.

F. B. Crocker

PROFESSOR FRANCIS BACON CROCKER is perhaps best known to the electrical fraternity through the invention, conjointly with Mr. S. S. Wheeler, of what is known as the Crocker-Wheeler electric motor, thousands of which are now in use in different parts of the world. In other branches of applied electricity, however, he has rendered equally distinguished service.



WHAT ELECTRIC TRANSMISSIONS WILL HELP TO AVOID.

COALLESS CITIES.

By Professor Francis B. Crocker.

THE entire exclusion of coal from large cities would be one of the greatest booms which advanced civilisation could confer upon them. The difference between city air and the fresh air of the country is almost wholly due to the enormous quantities of coal burned in the former. This combustion not only consumes the oxygen upon which life depends, but also contaminates the air with carbonic acid which is deleterious and with more or less carbonic oxide which is positively poisonous.

In addition to these gases, the particles of carbon in the smoke clog the lungs and spread in every direction the most penetrating form of dirt. The first thought whenever London or Pittsburgh is mentioned is of their smokiness and the permanent gloom which it casts over these cities. The dust which arises from the ashes of the coal consumed in cities passes out through chimneys and is also blown about while being handled or carted, contributing still another very disagreeable atmospheric impurity.

The total consumption ot coal in New York City is estimated at about 6,000,000 tons per annum. This requires for its combustion 16,000,000 tons of oxygen, producing 22,000,000 tons of carbonic acid, the whole of which is poured into the air of the city in the course of a year. Let us consider to what extent the air is also vitiated by the breathing of men and animals. The average quantity of carbonic acid exhaled by a human being is about 600 pounds per annum, and taking the population of New York at 1,800,000, the aggregate weight produced in this way is 540,000 tons. This figure may be increased to 700,000 tons to include the carbonic acid expired by animals. This total, however, is only about 3 per cent. of the amount due to combustion ; hence, the air of cities should be nearly as pure as that of the country, provided the latter cause of comtamination could be eliminated.

Furthermore, the horses and carts employed to handle coal and ashes add very considerably to the crowding,

dirtiness and unsightliness of city streets. In short, it requires little consideration to appreciate how greatly the riddance of coal would clear the atmosphere of a city. In answer to these statements it might be urged that in actual sickness and death rate large cities are not very different from the country. This, however, is due to better sanitary arrangements, better pavements and conveyances in wet weather, and other comforts afforded by the city. The fact remains that country air is much purer, the difference being very noticeable particularly in recuperating after an illness.

The conditions of the great problem of entirely excluding coal from a city may be stated as follows: Artificial illumination, motive power, heating, cooking, manufacturing, and various domestic operations, now performed with the aid of coal, must be accomplished without bringing coal or any objectionable substitute into the city. But how can such a radical and stupendous scheme be accomplished?

The first reply to this, as to all other apparently unanswerable questions, would almost certainly be, "By electricity, of course." In this instance the answer might seem to be the only one worthy of consideration. Nevertheless, there are other possible methods. For example, all of the requirements stated above could be fulfilled by producing steam at a station located beyond the city limits, and transmitting this steam to the various points where it would be utilised for heating, cooking and operating engines, the latter being also used to drive dynamos for supplying electric lamps.

One serious objection to this scheme would be the enormous expense of the necessary piping which would have to be of large diameter and of great strength. The loss of heat and condensation which would occur in such a vast system of pipes would also be fatal to this plan. The difficulty of laying large pipes in the streets and buildings and the practical impossibility of preventing them from leaking are additional troubles which would be encountered. Even the merely local distribution of steam from central stations situated in cities, and very near to the district to be supplied, has not been very successful in most places where it has been attempted, and the difficulties would be greatly magnified by increase in distances and complication. Similar objections apply to systems which employ hot water in place of steam.

The conversion of all fuel into gas, in a plant outside of the city, and the distribution of this gas for lighting, heating and power purposes would avoid some of the nuisances attending the use of the coal itself. This plan, too, has the merit of convenience since it saves the trouble of handling coal, for example, and also frees the city from smoke and ashes; but the consumption of oxygen and the production of carbonic acid would still remain as great as with the ordinary use of coal. There would also be considerable danger of explosions and fires due to leakage of the gas. As a matter of fact, however, gas has been the chief means of artificial illumination in cities for the greater part of the present century, and for heating, as well as for power, gas has been quite extensively employed in recent years, particularly in those favoured regions where it is supplied by nature.

The use of gas, however, fails to fulfill the conditions of the problem as laid down, since, as just noted, it vitiates the atmosphere to the same extent as the ordinary, aboriginal method of burning coal under our very noses.

Almost everyone will admit that upon electricity alone hangs the only hope of banishing coal and its disagreeable accompaniments from cities. The realisation of this hope may seem quite improbable, or, at best, not likely to be accomplished in less than fifty or one hundred years. As a matter of fact, however, the scheme is perfectly feasible from the engineering standpoint and would undoubtedly be a financial success as well. The only questions would be those concerning the best methods to employ.

If a suitable water power be available within a reasonable distance, it would naturally be utilised for driving the dynamos to generate electrical current for supplying a city. In the case of nearly all other large cities, however, the power would almost necessarily have to be obtained from coal, which would be brought to one or more large stations, located on the outskirts of, or at a sufficient distance from, the city, so that the latter would be free from smoke and other disagreeable consequences of coal combustion.

Let us assume that a large city is to be supplied with light, heat and power from a station located at a distance of 10 miles away. The site should be specially selected with a view to obtaining coal directly from railroads or vessels with the minimum expense and handling, the cars or boats being unloaded into the bins of the station. It would be necessary also to have an ample supply of water for the boilers, and, if possible, for condensing purposes as well. The generating machinery to be employed would depend upon circumstances, but it would probably consist of triple or quadruple expansion engines of 20,000 H. P. each. To be sure, such large engines have never been built for land use, but marine engines of about that size are in successful operation on transatlantic steamers and also on men-of-war, and there is certainly every reason why the design and construction of a land engine should be far less difficult than that of a marine engine, provided there is a demand for the former. These engines would be directly coupled to large dynamos of equivalent capacity.

It might be supposed that the two or three-phase alternating currents would be the only ones available for such a system, but it is possible that the single-phase, or perhaps even the direct current might be adopted. In any case a high potential of 10,000 volts or more would be required. The total capacity of the plant should be at least 100,000 horse-power, even in the beginning, and would have to be increased to several times that amount to satisfy all the wants of a large city. The high potential could be generated by the dynamos directly, but it might be wiser to employ step-up transformers, in which case the dynamos need produce only a reasonable and safe potential. If direct current generators were employed, they would have to be put in series, say four machines, generating 2500 volts each.

The current generated by the dynamos would be carried by overhead or underground conductors to the limits of the city, where the pressure would be reduced by step-down transformers to about 2500 volts in one or more stations, located at convenient points. The distribution of the current would be accomplished by running underground conductors from these main transformer stations to transformer sub-stations where the potential would be brought down to 250 volts for feeding lamps, motors, etc., by the three-wire system.

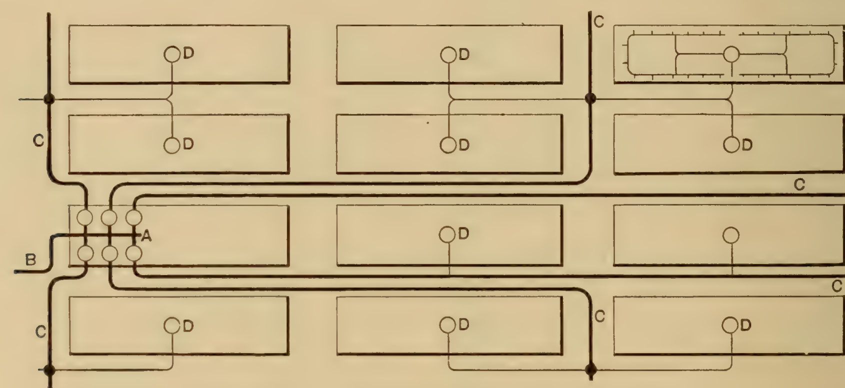
These sub-stations should be quite numerous, so that the local distribution at low pressure shall necessitate only the minimum weight of copper for the conductors. This local distribution usually involves the principal cost and also variation in the voltage of large electrical lighting systems, and it is also a fact that the number and complication of conductors and branches required for these local circuits is very great and enormous expense and trouble are entailed in laying and maintaining them.

The following plan might therefore be adopted to simplify this part of the system as far as possible. It consists in having a transformer sub-station in each block of the city to be supplied with current. Local circuits from the secondary of the transformers would be carried around the block. These circuits would not be dangerous since they would be operated at only 250 volts, and they could be strung as aerial wires supported upon fixtures or brackets attached to the roofs or back walls of the buildings, or they might be run in troughs, laid on the tops of the houses. Strong objections would probably be raised against allowing wires to be put up in this manner, but it should be remembered

that they would be entirely out of sight from the streets and would save the constant and very serious nuisance of digging up the latter for making connections to the individual houses. With overhead wires this could be done with trifling expense and trouble. All reasonable objections to these conductors are really less weighty than digging up the streets a single time to make or repair a house connection for gas or electric lighting.

The sub-stations would occupy only a part of the cellar in some building in each block, and there would not be sufficient noise or vibration from stationary or even rotary transformers to be at all perceptible in the rest of the building. The only precaution necessary would be the locking up of the transformers in a room accessible only to a regular attendant who could take care of ten or more stations, visiting each occasionally to examine the apparatus and perhaps also to regulate the voltage or to connect in circuit more transformers during the hours of heavy load. These last two operations could be performed electrically from a central station or automatically by clockwork, if desired.

The general arrangement of circuits is represented in the diagram on this page, in which *A* is the main transformer station, supplied with electrical energy at 10,000 volts from the generating station by the transmission conductors *B*. The pressure would be here brought down to 2500 volts and the current would be distributed by the feeders *C C C* to the transformer substations *D D D*, which would convert it to 250 volts for feeding the local distributing conductors, the latter being represented in the upper right hand corner of the diagram. Each building would be supplied by a branch connection from these conductors, as indicated by short projecting lines. For simplicity, the circuits are represented by single lines, but each may consist of two, three, or four wires, according to the system adopted.



DISTRIBUTION OF ELECTRICAL ENERGY IN A BIG CITY.

The existing underground conductors for incandescent and arc lighting could also be utilised and supplied with suitable current from sub-stations which might consist of the present generating plants operated by electric motors in place of the steam engines employed at present. Since this whole scheme will probably depend on the question of expense, it will now be necessary to go through a rather tedious estimate of the cost of electrical energy produced and delivered in this way. A high authority, Dr. Charles E. Emery, in a paper recently read before the American Institute of Electrical Engineers, stated that steam power can be generated continuously every hour in the year for \$35.54 (£7 2sh. 2d.) per horse-power, or 0.4 cent (0.2 d.) per hour. This is on the basis of a consumption of 1.25

pounds of coal per I. H. P. per hour, costing $2.24 (9 sh.) per ton. The engine economy thus assumed appears extremely high, but it could, doubtless, be realised in a very large plant designed and operated in the best possible manner with high pressure steam, automatic apparatus for handling coal and other means designed to secure the maximum economy.

In most practical cases the work of an engine is not uniform, and Dr. Emery, therefore, estimated the cost when the maximum load is 20,000 H. P.; but the average load is only 63.8 per cent. of this, or 12,760 throughout the year, and Dr. Emery finds the cost of this to be 0.5 cent (0.25 d.) per horse-power-hour. In the plant under consideration the average load would probably be a still smaller percentage, but on the other hand, it would be larger than in ordinary electric lighting, because the current is to be used for many different purposes which would tend to make the load more uniform. Let us, therefore, assume the average load to be 50 per cent. of the maximum. This would increase the cost per horse-power hour to about 0.6 cent (0.3 d.), it being understood that in such a large plant there are a sufficient number of engines, so that it is never necessary to run any of them at less than three-quarters of their full capacity.

The loss in converting the mechanical power into electrical power, which would not be over 5 or 6 per cent. in such large machines, the interest on, and maintenance of, the dynamos, transformers, as well as the labour involved, would raise the cost to about 0.8 cent (0.4 d.) per electrical horse-power-hour, produced by the generating plant. Allowing for the various incidental expenses which it is so difficult to include in an estimate, this cost may be taken at the simple figure of 1 cent (0.5 d.) per horse-power-hour.

The conductors for transmitting the current, the maximum value of which is about 7500 ampères at 10,000 volts, should have an aggregate cross section of 7.5 square inches, or 9,500,000 circular miles, and would weigh about 150,000 lbs. per mile, or 1,500,000 for 10 miles. For the direct or single-phase current two of these sets of conductors would be needed to make a complete metallic circuit. The two-phase system, using four wires, would also require the same weight of copper, but with only three wires, or with the three-phase system, less copper would be necessary. For simplicity, however, the total weight of copper will be taken as 3,000,000 lbs., which, at 14 cents (7 d.) per lb., would cost $420,000 (about £84,000).

The insulation, armour and laying would bring the investment for these conductors up to about $1,500,000 (£300,000). Assuming 5 per cent. interest and 10 per cent. maintenance on this value, the annual expense for transmitting the energy from the generating plant to the transformer stations would be $225,000 (£45,000), which is 0.05 cent (0.025 d.) per horse-power-hour and makes the cost of the power at this point 1.05 cent (0.525d.)

The necessary stations, transformers and other apparatus for reducing the potential from 10,000 to 2500 volts would cost not more than $1,500,000 (£300,000), the interest, taxes and depreciation on which should not exceed 15 per cent. This, together with the labour and other expenses at these stations, raises the cost to 1.15 cents (0.575 d.) per horse-power-hour. There should be a sufficient number of these main stations (*B*), so that the feeders (*C C*) for conveying the current to the sub-stations (*D D*) need not have an average length of more than 2 miles.

The maximum current carried by these feeders is about 30,000 ampères at 2500 volts, and their combined cross section is 30 square inches. The total length is 4 miles, and the weight, 2,400,000 lbs., which, at the same rate as the other conductors, would cost $1,200,000 (£240,000), the annual charge upon which is 15 per cent. or $180,000 (£36,000), raising the cost per horse-power-hour to 1.2 cents (0.6 d.).

The expenses involved at the transformer sub-stations *D D* would be about the same as at the main transformer stations *A* which would bring the cost per horse-power-hour to 1.3 cents (0.65 d.). The mains which distribute the current to the houses in each block would have an aggregate area of 300 square inches, to carry 300,000 ampères at 250 volts. Their average length would not be more than 500 feet, even allowing for considerable indirectness in path. They would weigh 1,200,000 lbs. and would cost $600,000 (£120,000), which, at 15 per cent., would make the final cost of the current, delivered to the consumer, 1.32 cents (0.66 d.).

The importance of correct design for this system may be appreciated from the statement that these low-voltage mains would cost 100 times as much if they were one mile long instead of 500 feet, which would more than quadruple the total investment.

To avoid confusion, the losses of energy in the transformers and conductors were not considered in estimating the cost. The loss of pressure on the transmission conductors would be 8.6 per cent. at full load, 7 per cent. on the feeders, and 3.4 per cent. on the local distributing conductors. At the average load of 50,000 H. P. these percentages would be reduced to one-half of the above values. Adding to these the losses in the two transformations, which would be about 3 per cent. each, the total loss is found to be 15.5 per cent. This may be added to the cost per H. P. hour, making it 1.44 cents (0.72 d.).

Allowing also a handsome profit to be paid as dividends to the investors, and miscellaneous items, such as legal expenses, payments to the city for franchise, etc., the electrical energy could certainly be sold at 2 cents (1 d.) per horse-power-hour. While this figure is far lower than the rate ordinarily charged by central stations, it is by no means visionary. The Cataract Construction Company, at Niagara Falls, will sell electrical energy at $18 (£3 12 sh.) per H. P., per annum for large quantities, and since this can be used 24 hours per day throughout the year the cost per hour is only 0.2 cent (0.1 d.).

This shows the possibilities with very large plants, and since the cost of the coal is a very small item in the scheme herein outlined, the saving at Niagara due to water power, would not make a very great difference. The coal consumption in central stations is often 4 or 5 lbs. per horse-power-hour, whereas in Dr. Emery's estimate it was taken at 1.25 lbs., the difference being due to the enormous scale and improved methods of the 100,000 H. P. plant. The high rate of 12 or 15 cents per horse-power-hour which is usually charged for electrical current applies to the case of lighting, most of the machinery being practically idle for twenty hours out of twenty-four. When used for driving motors, the rate for current is ordinarily made one-half as high as for lighting, for the reason that the motors run 10 hours a day and chiefly during the time when lights are not being used. If the energy could be applied to many more uses it would tend to still further reduce the rate.

The electrical energy produced and delivered in the manner described above would be utilised for electric lighting according to the methods now in successful use which are too well known to require explanation. A branch would lead from the distributing conductors into each building and would connect with a system of wiring running to each room. This wiring would be just as necessary as the pipes for supplying water. Even now, in almost all new buildings of any importance, electric wiring is put in as a matter of course. The merits of electric lighting,—great convenience, cleanliness, the small amount of heat given off, its freedom from vitiating the air and many other advantages, are matters of every day observation.

This superiority is proved by the rapidity with which the electric light has been introduced in the last ten years, and the only reason why it is not adopted almost universally is the

fact that in many cases it is more expensive than gas light. But with the current supplied at 2 cents (1 d.) per horse-power-hour, the cost of running a 16-candle power lamp would be only 0.15 cent (0.075 d.) per hour which is about one-sixth of the present rates. Even if double rates were charged for electric lighting, because of the reasons explained above, it would cost only 0.3 cent (0.15 d.) per lamp-hour, which is one-half the price of gas at $1.25 (5 sh.) per 1000 cubic feet. If it were thus made actually cheaper than gas there would seem to be no reason why it should not be gladly adopted by everyone, whether rich or poor.

The advantages of the electric motor are similar to those of the electric light. Its compactness, convenience, cleanliness and comparative exemption from fire risk make it in every way preferable to steam or even gas engines. Being practically free from noise, vibration or smell, it can be placed in any position in a building and is, therefore, particularly suitable for use in cities where a manufacturer may occupy only the top floor of a building and yet may have his independent source of power

With the system proposed, small amounts of power could be obtained at substantially the same rate per H. P., *i. e.*, 2 or 3 cents per hour (from 1 d. to 1½ d.), as it now costs to run a large steam engine, in ordinary practice, thus putting the small workshops, which are numerous in great cities, on equal terms with the large factories. Electric motors can be applied to an almost infinite number of uses that are not practicable with any other source of power, such, for example, as driving small fans, pumps, grinding, polishing, washing and brushing machinery, and many other kinds of domestic and manufacturing appliances.

Electric cooking, while not as well established as electric lighting and motive power, is, nevertheless, being successfully introduced at the present time. Like all electrical methods, it is extremely clean and convenient. The heat can be obtained almost instantly and always of exactly the same degree, so that the various articles of food can be cooked to precisely the same extent each time. It is generally supposed that the expense would be excessive, but as the heat can be applied exactly where it is required, as for example, within the water to be heated, and as the current can be turned off and the expense absolutely stopped the moment that the cooking is completed, this method is really economical. If the energy were obtainable at the cost estimated, electric cooking would, undoubtedly, be much cheaper than the ordinary mode, without considering its other important advantages.

The fourth and last service to be performed by electrical energy is that of heating, and in this direction lies the only really serious difficulty to be overcome. To maintain a large building, or even a small private residence, at a comfortable temperature in very cold weather, calls for an amount of energy which is greater than that ordinarily required for lighting, cooking and motive power combined. Two or three of the ordinary electric lamps give ample light for a room of moderate size, but their effect on the temperature of the room is hardly perceptible, although it is a physical fact that they convert into heat practically all of the electrical energy supplied to them. It is also evident that the heat necessary to cook the food of a family would be insignificant in its influence upon the temperature of a house.

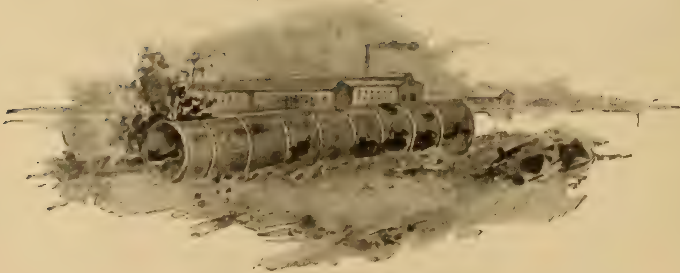
Nevertheless, electrical heating has decided advantages which go a long way towards making up for this apparent inadequacy. The peculiar neatness and convenience which it possesses, in common with other applications of electricity, are always powerful arguments in its favour. Furthermore, the entire energy supplied to an electric stove appears in the form of heat which is given off into the room. It can also be applied with great directness; for example, an electric heater can be incorporated in a footstool or rug.

Since it would be to the mutual interest of the customer and of the com-

pany supplying the electric current to make electrical heating feasible, it might be possible to charge lower rates for it than for the other applications. This could be done because the steady and long-continued load due to heating is favourable to the economical working of the generating machinery. Charging double rates for lighting would also help to make up the difference. It should be remembered that heating is required only during four or five months in the year and many days of that period are sufficiently warm so that little or no artificial heat is needed ; consequently the total expense per annum would not be very great. Whenever it is desired to regulate the temperature it can be done to a nicety with an electrical stove. In warm climates this difficulty in regard to heating would not exist, and the current could be applied to the other three uses with the same or even greater advantage than in colder regions.

Some method, like that here outlined, of supplying cities with energy on a large scale, is certain of adoption in the not distant future. Advanced civilisation will demand it whether it costs a little more than the present method or not. Progress does not always cheapen things ; it makes them better and more convenient. Living expenses are greater to-day than they were a hundred years ago and there is every reason to believe that they will continue to advance in the future. But at the same time comforts increase in a far greater ratio.

It is perfectly safe to predict that before the end of the next century and perhaps in a decade or two coal will not be brought into some of the big cities of the world, except perhaps in the form of specimens for mineralogical collections.



Louis Bell

DR. LOUIS BELL was, for a number of years, in charge of the power transmission work of one of the large electrical companies, and has become widely known as an acknowledged authority on that branch of applied electricity.

THE INDUCTION MOTOR.

By Dr. Louis Bell.

IN spite of the fact that the motor without a commutator is now in frequent use, and bids fair to take and retain a most important place in industrial operations, the rationale of its performance is as yet a sealed book to most of those who use it. That it works admirably, is singularly free from practical difficulties, and is in many, indeed, most, respects preferable to the ordinary continuous-current motor, is taught by a very brief experience ; but how it operates, why it operates so well, and what relation it bears to more familiar machines,—these are questions generally but half answered, if answered at all.

The truth is that the complication of the induction motor is far more apparent than real, but its actual simplicity has been hidden by the unnecessary abstruseness with which its theory has often been treated and by the adoption of various working hypotheses that have been sometimes more convenient than accurate.

In the term induction motor the writer intends to include all those alternating current motors in which either the field or armature current, as the case may be, is derived, not directly from the working circuit, but by induction from that member of the motor, whether field or armature, which does receive current directly from the line. In other words, while in continuous current motors current is sent into both field and armature, in induction motors only one of the pair is directly energised, but this one transfers energy by induction to the other.

Such motors may be of the so-called polyphase type, or they may not, but they have in common this property of being at once transformer and motor. This duplex character enables us to dispense with all moving contacts for leading current from field to armature windings, but produces an apparent complexity of action that is, at first sight, puzzling. To understand just what goes on in such a motor we must, for the time being, separate in our minds the motor and the transformer functions, put aside theories and come down to the fundamental principles that underlie all motors. It is not surprising that the induction motor has been partially misunderstood when we realise how long electricians fumbled about the truth concerning continuous-current motors.

The first fact in the theory of electric motors is that a wire, carrying an electric current, is attracted or repelled when brought in the neighbourhood of

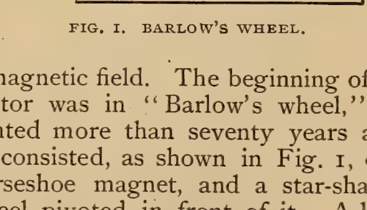
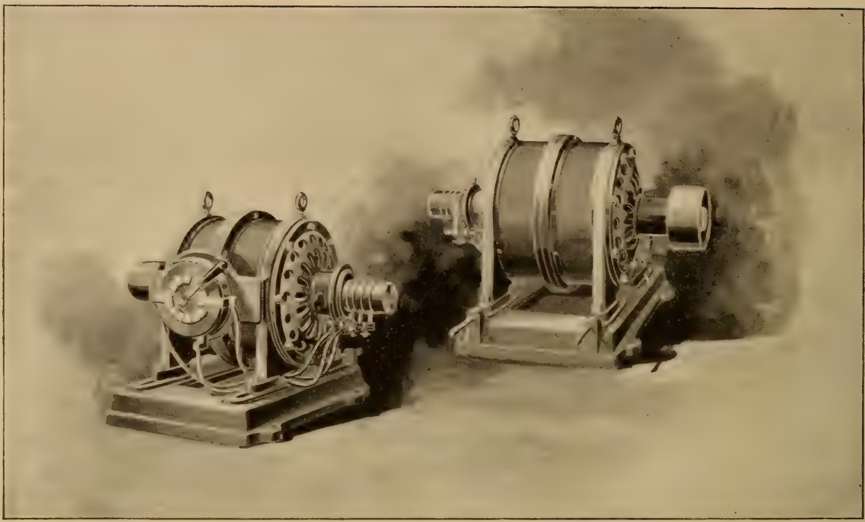


FIG. I. BARLOW'S WHEEL.

a magnetic field. The beginning of the motor was in "Barlow's wheel," invented more than seventy years ago. It consisted, as shown in Fig. 1, of a horseshoe magnet, and a star-shaped wheel pivoted in front of it. A little trough of mercury, into which one or more of the spokes of the wheel constantly dipped, served as a commutator. When current from a battery was sent from the axle of the wheel through a



TWO-PHASE MOTORS, BUILT BY THE STANLEY ELECTRIC MFG. CO., PITTSFIELD, MASS., U. S. A.

spoke to the mercury, this spoke moved over into the field until the commutator broke circuit with it and the action was transferred to the spoke next following. Reversing the direction of the current, or the poles of the magnet, would reverse the direction of rotation. This rudimentary motor contains the three elements which form the essential parts of every motor,—a magnetic field, a moveable wire carrying current, and means for putting that current into and out of action when it begins or ceases to produce useful effect.

At bottom, all motors consist of these three elements, often much elaborated and complicated, but, after all, serving just the same simple purpose. However involved the actions, however inter-related the parts of a given machine may be, they become intelligible when we cut loose from minute analysis of their relations, and consider them broadly, as performing the operations and constituting the parts that we find common to all their kind. In practical motors the field instead of the armature may be moveable, the windings may be enormously complex and the commutating function may be performed by stopping and changing the direction of the current at the generator itself; but the general principles remain the same. In ordinary continuous-current motors the field is supplied by an electro-magnet, energised by the whole or a part of the armature current, and the armature consists of very many turns of wire, instead of a single loop or the fragment of a loop found in Barlow's wheel. The commutator is correspondingly complicated, but it still serves merely to keep the current flowing in the moving wires in the proper direction at the proper time.

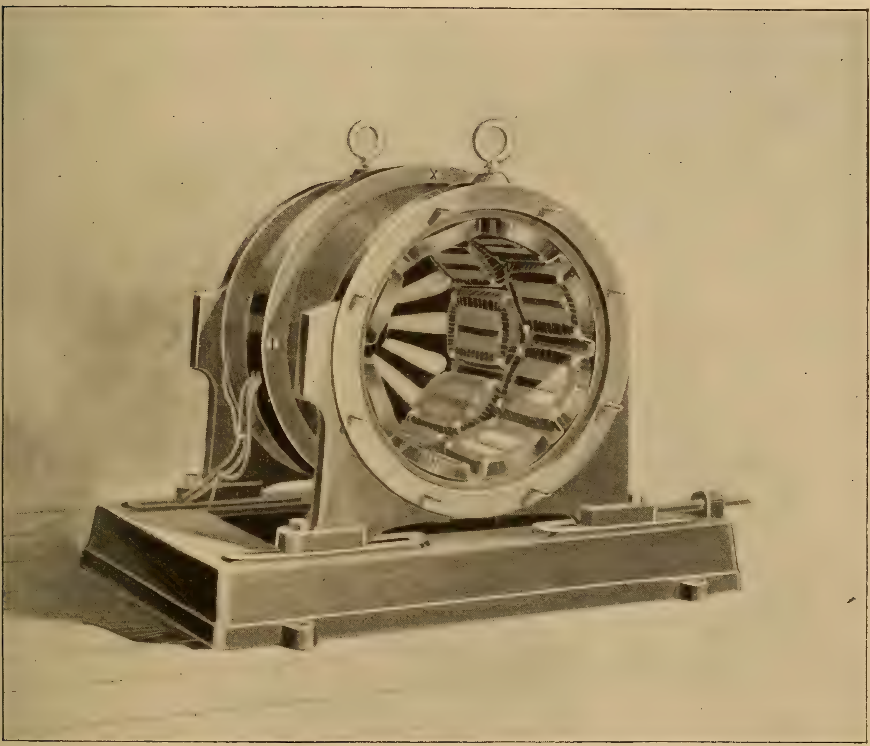
The windings are on an iron core to make it easier to obtain a powerful field, but, so far as the principle is concerned, the armature core might be of wood or entirely absent. If present, it is not of the slightest importance, save mechanically, that it should revolve with the wire; so far as the theory of the motor is concerned, the wires might as well be wound on a frame and revolve outside a stationary core. Indeed, such an arrangement has been tried.

As regards alternating motors, most of the early efforts were directed toward an intelligent application of the same principles that had proved successful with continuous currents. These first attempts failed, not because any new general principles were needed, but by

reason of numerous minor difficulties inherent in the use of rapidly alternating currents. We need not go into the details of all such experiments. Suffice it to say that irremediable sparking has prevented the use of such motors, except in the smallest sizes. In other words, the ordinary process of commutation, while quite capable of performing its usual function of distributing the current to the armature conductors, when and where it is needed, could not successfully be carried out with alternating currents.

In the induction motor, the attempt to properly organise the armature currents by commutation is abandoned and, instead, the armature currents are generated by the transformer action of the field at such times and points as to place them in effective relation to the field magnetism for producing rotation. The character and purpose of this organisation is very often somewhat misunderstood. This is not remarkable in view of the fact already mentioned that the principles of the continuous-current motor came to the surface somewhat gradually.

It is, in fact, only a few years since the electric motor was popularly explained in the following manner :—The armature current magnetises the armature, producing powerful magnetic poles which are attracted by the poles of the field magnet, thus pulling the armature around. The commutator enables us to keep these armature poles at fixed points where they will be most powerfully attracted.



THE STANLEY MOTOR FIELD.

There were grave discussions as to whether the pull was not exerted on the armature core, in which, of course, the "poles" were situated, instead

of on the conductors. For many years motors were built on this theory, and all the ingenuity of the inventor was spent in getting a good, strong set of armature poles to confront the field magnets. Not until the pole

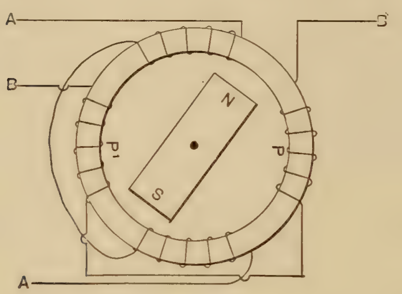


FIG. 2.

theory had been abandoned, did the electric motor arrive at its present point of excellence.

Unluckily for the progress of the art, the induction motor has been developed largely under a similar simple and convenient hypothesis, even more universally held, but often serving to conceal the facts. The induction motor started out in the polyphase form and on the theory of a rotary magnetic polarity, which dragged the armature around after it.

Diagramatically this idea can be

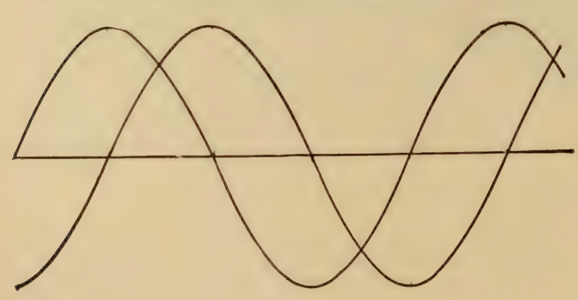


FIG. 4.

expressed as follows: Let an iron ring, Fig. 2, be wound with two separate circuits *A A* and *B B*, and inside the ring let there be pivoted a bar magnet, *NS*. Now send a current around *A A* so as to make a south pole at *P* and the corresponding north pole at *P′*. Of course, *NS* will begin to move toward the line of *P P′*. Now let the current in *A A* decrease, and an increasing current, in the same direction, be sent into *B B*. The two currents, acting together, will produce a resultant magnetisation with its poles shifted along to a new position as $P_1 P_1'$ (Fig. 3). The armature *NS* will follow along, as shown in the figure, and, finally, when the current in *A A* has died out and that in *B B* is at its maximum, the poles will take the line $P_2 P_2'$, as in Fig. 5, and so on, the magnet *NS* continually scurrying around after the shifting polar line, like a kitten chasing her tail.

To make the action symmetrical, the currents should be of equal magnitude

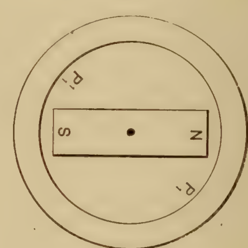


FIG. 3.

and so related that the one is at its maximum when the other is at a minimum, *i. e.*, a quarter period apart when alternating currents are considered, as shown in Fig. 4. This explanation is simple and accurate as far as it goes, but it does not include all the conditions met in practical induction motors. It neglects the fact that there is a distributed armature winding and that current is supplied to it by the transformer action of the machine.

The rotary pole theory, as above outlined, has as its fundamental idea a resultant magnetisation, produced by the combined action of two or more energising circuits and revolving as the currents in these circuits follow each other in phase. These rotary poles drag around the armature in virtue of the

currents induced in its conductors. Such a theory applies very neatly to certain cases, as the comfortable old pole theory of the continuous-current motor just fitted the machines that were built on it as a foundation. But it has done mischief by distracting attention from the correct organisation of the armature circuits, the reason and necessity for which it does not properly take into account, and it has to be wofully stretched and patched to even partially cover induction motors in which there is no shifting resultant magnetisation or no phase difference in the currents supplied.

This insufficiency is not remarkable when we realise that the early induction motors were not of a character to disclose readily the principles of their action or their analogy with continuous-current motors.

Most of the rudimentary induction motors, such as that shown by Baily before the Physical Society of London in 1879, and some of those built by Ferraris a few years later, had solid armatures of copper or iron, without windings, which, while very simple in appearance, were not so in principle. In reality, the same elements that are fundamental in direct-current motors appear in all induction motors, and

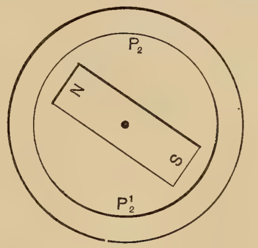
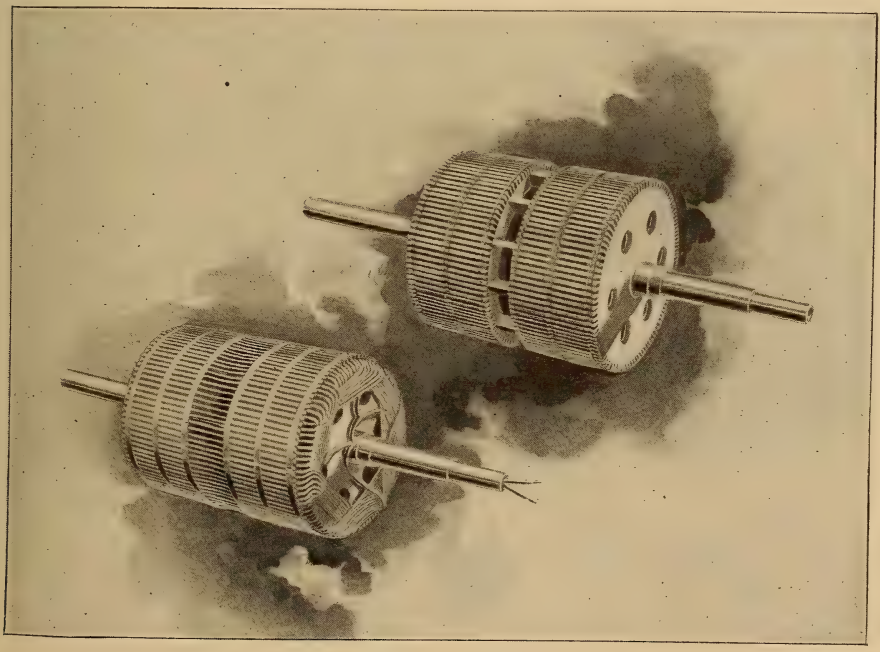


FIG. 5.

the same simple facts serve to explain both kinds of apparatus.

Although the mathematical theory of the induction motor is somewhat complex, particularly if discussed from the standpoint of rotary poles, the general character of its action is both simple and strikingly similar to that of other kinds of electric motors. Certain types of induction motor are of more easily comprehended action than others, and



STANLEY MOTOR ARMATURES.

perhaps the simplest to understand, although not at all the simplest in appearance, is the Stanley-Kelley motor, of which the construction is clearly shown in the illustrations on pages 242, 243 and 245.

The field of this machine is duplex, consisting of two quite distinct sets of salient poles, placed side by side, with the poles of one field spaced inter-

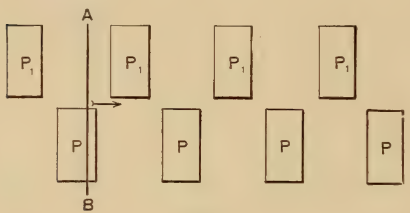


FIG. 6

mediate to the poles of the other. Each field has its own set of windings and the two are quite independent of each other. The coils seen inlaid upon the pole faces, and meeting the two fields have a purpose of their own, but have no essential part in the principles of operation. The armature is double, like the fields, but the conductors are wound straight over both cores. In diagram the essential parts of the apparatus are arranged as in Fig. 6.

Let *A B* be an armature conductor. Its connections may be put aside for the present. Suffice it to say that it is so connected to the rest of the winding that it works with and not against its neighbours. Each set of poles is supplied with windings forming a separate circuit. Now suppose the pole *P* to be powerfully excited. A current will be set up in *A B*, acting as the secondary of a transformer. Suppose, then, the poles P_1 to be energised by a current a quarter phase from the current around *P* and in such direction as to produce a field that will attract *A B* when carrying the current set up by *P*. We then have the following state of things:—

The armature conductor *A B* is still carrying a strong current, delivered to it by induction from *P*, while P_1 is so magnetised as to attract this current. Hence, *A B*, with other conductors, similarly attracted, moves over and sets the armature into rotation. We have here all the essential elements of the generalised motor. A movable conductor *AB*, carrying a current delivered to it by *P* (induction serving in lieu of brushes), is attracted by the magnetic field set up by P_1. Means for putting that current into and out of action is supplied by the relations of the two sets of poles. By the time *A B* has moved over half a pole-space, the original current in it has died out, and the pole P_1 is acting as transformer, sending into *A B* an induced current which is attracted by the next pole in the set *P*. And so the two sets of poles alternate occupations, *P* serving as transformer, while P_1 is acting as field and *vice versa*.

The object of supplying these poles with currents a quarter phase apart, is to ensure that the field *poles* and the armature *currents* shall be simultaneously active. In this motor the transformer and motor functions are very obviously separated. One set of poles furnishes armature current, while the other furnishes field magnetism to attract this current. At each alternation in the direction of the primary current, the

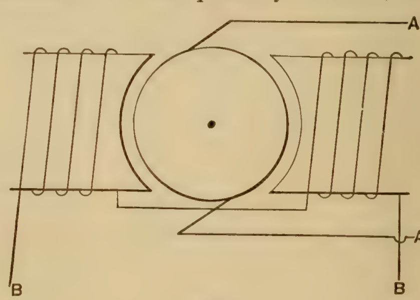


FIG. 7.

two ends of the motor exchange functions. Each set of poles is separately magnetised by an alternating current, and there is no resultant magnetisation of anything whatever. The action is quite analogous to that of a continuous-current motor in its simplicity, in spite of the extraordinary differences in the method of getting at the result.

In this brief explanation of the opera-

tion of one type of induction motor, all non-essential actions have been ignored as in the previous exposition of the rotary pole theory. It is not even necessary to use two currents in different phases to supply the energy; it is necessary only to provide a magnetizing current for the field and a transformer primary to furnish current to the armature in phase with the field magnetism. We might, for example, arrange a motor, as shown in Fig. 7. Here the magnetising current would be supplied from the circuit *B B* while the circuit *A A* would supply energy current to the armature. We should there simply require the energy current to be in phase with the field excitation.

The same result can be obtained by using inducing poles instead of brushes, if the above requirement be fulfilled. Such an arrangement is shown in Fig. 8. The magnetisation is furnished, as before, by the circuit *B B*, while *A A* would be the primary winding of the transformer poles which furnish the secondary current in the armature conductors. The current in *A A*, which supplies all the energy, is nearly in phase with its electromotive force. The induced armature current is, of course, opposed in direction to its primary, but substantially in phase with it. But it is necessary that the magnetisation and magnetising current should be in phase with the armature current in order to give the requisite force between the field and the moving conductors. Hence, since the magnetising current, here, as usual, is about a quarter period behind its electromotive force, this electromotive force should be a quarter period ahead of the main electromotive force which supplies the primary current *A A*.

In this case we have an induction motor in which all the currents concerned are practically in the same phase, but which requires a separate electromotive force to supply magnetising current. This exciting electromotive force is small enough not to set up any considerable transformer action which might otherwise go on, and hence represents very little energy. This is the arrangement of the so-called monocyclic motor.

It is interesting to compare this with the motor of Fig. 6. In both, the magnetizing and transformer functions are separated, in the former tempo-

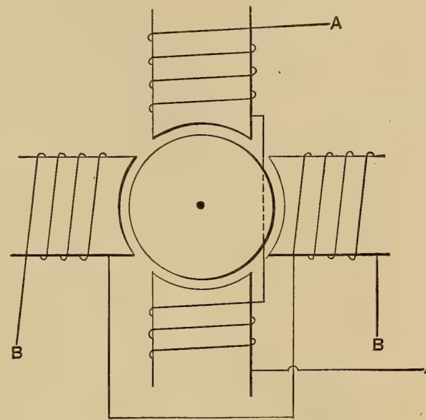


FIG. 8.

rarily, in the latter permanently. The former supplies energy equally from both sets of poles; the latter, from only one set.

Recurring to Fig. 6, we might, so to speak, push both sets of poles into the same plane. We should then have a quarter-phase motor of the kind gen-

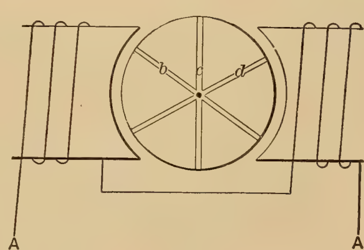
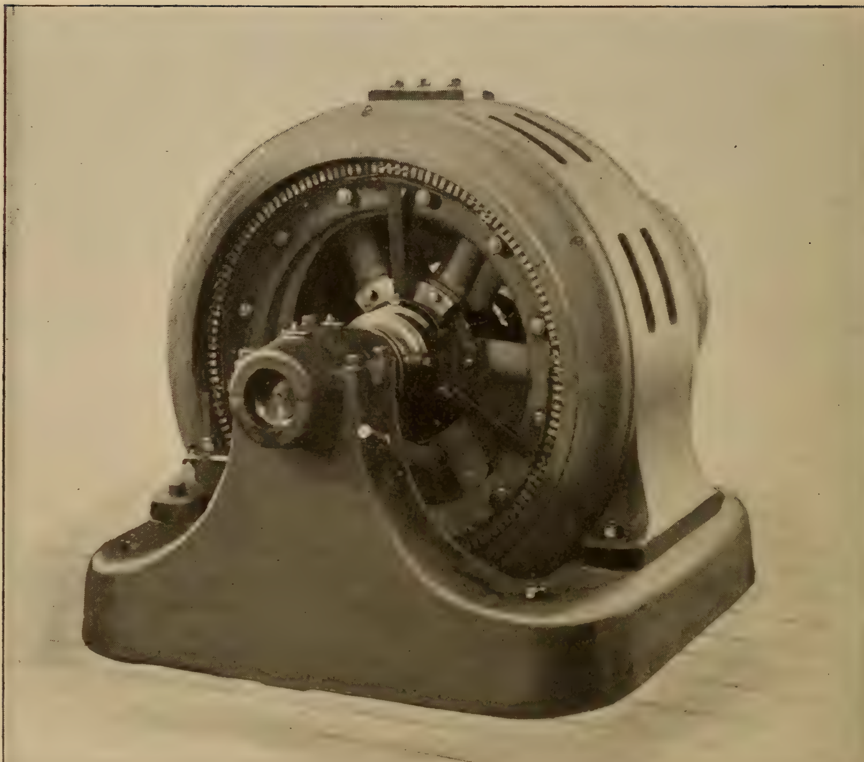


FIG. 9.

erally classified as "rotary pole," but the action really going on may be explained in precisely the same manner as before. One set of poles still acts as transformer, and the other as field, and they periodically exchange works as before. The so-called shifting of the poles is nothing more than this exchange of functions.

The apparent rotation of the poles is, in substance, only an alternation of



AN ALTERNATING-CURRENT INDUCTION MOTOR OF 125 HORSE-POWER, BUILT BY THE GENERAL ELECTRIC CO., NEW YORK.

work between induction and magnetisation that can take place quite as well when the two sets of poles are separated and there is not even the appearance of rotation. There may be true resultant magnetisation, but it is non essential.

It is not necessary that there should even be field poles and inductor poles in an induction motor; a single winding can be made to serve both purposes at once. Fig. 9 shows how this can be accomplished. Let *A A* be the magnetising circuit, and *b c d* closed armature coils. An alternating current, applied to *A A* will produce, of course, an alternating magnetisation, but no turning, since the armature coils are affected symmetrically, and such an arrangement will not start. We have the field and a current in the armature conductors, but nothing to put or keep the current in effective relation to the field. If there is no self-induction, it will do no good to revolve the armature. If, however, there is self-induction in the armature, the currents, set up in it, will lag behind the electromotive force set up by the field, so that there will be current flowing through the armature at times when the field is still strong.

Now spin the armature, and the conductors will have an angular displacement with respect to the field, in amount depending on the speed, and in direction depending on the direction of rotation. We now have a magnetic field and a moveable conductor carrying current, and with a definite angular displacement with respect to the field. The result is, of course, torque. If the speed of the armature approaches synchronism, so that the angle between coil and field is

fairly steady as the field alternates, the machine will run tolerably well as a "single-phase" motor.

It is worth noticing that in every motor we must have not only a magnetic field and a current in a moveable conductor, but a stable angular relation between the two to ensure an effective torque. In continuous current motors this relation is determined by the position of the brushes; in the quarter phase motor, by the relation of the poles in space and the two currents in time, in the monocyclic motor, by the space relation of the inductor and magnetising poles; and in the "single phase" motor by the angular speed of the armature, and the self induction. Consequently, we find that while the first three classes have quite uniform conditions of running, the last is much more sensitive to changes of resistance, inductance and load. Induction motors using three or more-phased currents, do not differ essentially from quarter-phase motors in principle.

We have now looked over the class of induction motors in a somewhat cursory way. They constitute an important type on account of their freedom from moving contacts, and their unique applicability to cases where alternating currents are necessary or convenient. Like continuous current motors, they depend on very simple principles which are common to both, but unlike the former, they show a wide diversity in the devices for keeping conductors and field in effective relation. The general result is the same, however, and a well-designed induction motor behaves very much like its older rival. Field and armature current are about as easy to obtain in one type as in the other, and the brush and commutator is no more effective in making pole and current pull together than is an accurate relation in space and time of inductor and magnetising poles.

Practically, therefore, there is little difference between induction and other motors in efficiency, output or general character. As induction motors become more familiar they will constantly win more friends by their genuine simplicity. To point out this simplicity has been the purpose of this rudimentary discussion.

ELECTRICITY FOR PROPELLING RAILROAD TRAINS AT VERY HIGH SPEEDS.

By Hiram S. Maxim.

ONE HUNDRED AND FIFTY MILES AN HOUR.

THE steam locomotive has been in use for about two generations, and perhaps no other single machine ever invented has had so much influence on the civilised world. From the first it has been in the hands of highly-trained and skilful engineers. An infinite number of experiments have been made which have, from time to time, led to various improvements, until to-day we find the locomotive a very perfect and highly developed machine. I think I may say that engineers have just about come to the end of their tether in improving it. Even 30 years ago it had reached a very high degree of perfection, and the speed at that time was almost equal to anything that can be attained to-day.

During the past year two great American and two great English roads have been competing with a view of ascertaining how high a train speed could be obtained with the most improved types of locomotives, and when it is remembered that the American and English types differ considerably in construction, that they have been developed under different conditions, and that the difference between the highest and the lowest speeds at these trials has been less than 2 miles per hour, it will be seen that there is very little room for improvement unless some radically new means of propulsion can be devised.

In order to obtain high speeds, it has been necessary to increase the weight and size of locomotives and both have now reached their limit. The boilers are already made so large that they have to be mounted very high in order not to interfere with the wheels, and the weight is already so great that any further increase would be dangerous to the permanent way. With everything as large and strong as it is possible to make it, and with the employment of the most perfect material, we are able to obtain a train speed of about 60 miles an hour, and I think this can never be greatly exceeded with an engine driven by steam. In fact, trains are now driven as fast as it is possible to drive them with the amount of power that can be developed within the limit of space and weight admissible on the modern railroads.

If we wish to obtain higher speeds we must employ more power in proportion to weight than we now have at our disposal with the modern steam-driven locomotive. In order to greatly increase the power it is necessary that the source of energy should be stationary and the energy transmitted to the moving train, and the only practical way of accomplishing this on a large scale is by employing electricity.

An electric engine may be made to develop almost any amount of power, and still be well within the weight and bulk of an ordinary locomotive. It is true that some difficulties have been encountered in electrical locomotives. It has been found difficult to make a motor that would work well at both

FROM A PHOTO BY MAULL & FOX, LONDON.

Hiram S. Maxim

HIRAM S. MAXIM'S remarkable achievements in automatic machine guns and improved artillery have made his name familiar the world over. His not less distinguished work in electricity lends special interest to his present article on electric train propulsion.

very low and very high speeds, but I think this trouble could be surmounted by employing a considerable number of motors on the same locomotive, arranged in such a manner that the driver or engineer could couple them at will in many different ways.

When starting, they could be all coupled in series, so that the high tension current could be employed advantageously without injury to the armatures. Then, as the speed increased, the coupling could be changed, step by step, from series to multiple. Thus, at very high speeds, especially in ascending a gradient, all the motors could be connected in multiple, when the highest amount of energy would be developed. In this way, I think, many of the troubles heretofore encountered could be completely overcome.

In regard to the question of supplying a long road with a powerful high tension current, I would say that when trains are propelled by steam, it is necessary to employ a large number of separate steam engines. Why, then, should there be any objection to using a large number of steam engines for an electrical railroad? It certainly costs no more to run a stationary engine than a locomotive engine, and the engines for supplying the current could be placed at regular intervals along the line. The tension of the current might be, say, from 2000 to 5000 volts. The main conductors should be thoroughly insulated and protected from atmospheric influences. The actual rubbing surface, transmitting the current to the moving train should be in relatively short sections, and connected to the main conductor only while the train is actually passing, the latter being provided with suitable apparatus for switching the current in ahead of the train and cutting it out after the train had passed. In this manner there would be very little loss of current, even if at a very high tension, and nearly all danger of accidents would be avoided.

With the present steam engines it is necessary to use the very best quality of coal, costing at least twice as much per ton as the cheap steam coal. A locomotive steam engine has, of necessity, to be a high-pressure, non-condensing engine, and the exhaust steam has to be discharged against considerably more than an atmosphere of pressure, because it has to be employed for inducing the draught. Moreover, for reasons before stated, a locomotive engine must be limited in size.

A stationary engine, however, may be made of any size. It may be a compound condensing or a triple expansion engine. Large boilers may be employed, having a very large heating surface in proportion to the coal consumed; and the grate surface may be of any size, so that a very cheap coal may be employed. In this manner the cost of developing a given horsepower costs 60 per cent less than it does on the locomotive.

With the latest improvements in electrical transmission, I think I am inside the limit in stating that power may be transmitted at a loss no greater than 25 per cent. It will therefore be seen that the actual cost of power, delivered on the line, will be considerably less than at present. Moreover, with the steam locomotive it is necessary to propel over the line a very heavy locomotive and a large supply of coal and water. In the electrical locomotive the engine can be much lighter, and, of course, the coal and water can be completely dispensed with. Therefore, in the electrical locomotive we shall have cheaper power and a very much lighter train to propel. The reduction in weight will also greatly reduce the wear and tear of the line.

As to the question of speed, I see no reason why we might not expect to double the speed of steam-driven trains. Ordinary electric trains should travel at the rate of 90 or 100 miles an hour, and express trains at, say, 120; but in order to do this, it would be necessary to so construct the carriages as to enable them to pass through the air without any great resistance. The train should be pointed at both ends, and have the appearance of being all in one piece; even the wheels and axletrees would have to be boxed in.

I find in my experiments that atmospheric skin friction on a smooth surface is so very small that it need not be considered as a factor at all, but the power required to drive a rough or irregular body through the air is very great.

Electricity could, of course, be advantageously employed on existing roads, but if special roads were to be constructed, say, for taking passengers from London to the sea-coast, a comparatively cheap line could be employed, and as the electrical train would be vastly lighter than the steam train, extensive grading and tunnelling would not be necessary. The line might follow, approximately, the contour of the country.

In the steam-driven train great power is required to enable it to mount even a slight gradient, and all this energy is wasted in heat and friction on the brakes in descending the next grade. The extra amount of energy consumed by an electrically-driven train in mounting a gradient could again be utilised in descending the next gradient, because the descending train, moving at a high velocity, instead of having its speed checked by the use of brakes, could turn a switch in such a direction as to convert the motors themselves into generators which would actually send a current into the line which would be available for the use of other trains. The storing of energy developed by a descending train has always been a desideratum ; it is quite impracticable to use it with our steam-driven trains, while it is a simple matter in trains driven by a cable or by electricity.

Some engineers may imagine that a great deal of trouble would be encountered in arranging the sidings, switches, etc., of a large station. I think this might be completely obviated by using steam locomotives for local purposes, exactly as small steam locomotives, called "switch engines" in the United States, are now used, the electricity being only on the main lines. All trains, except those on the main lines, could be moved as at present, electricity being employed only for high speed between stations.

In the foregoing I have pointed out only what is available to the engineer at the present moment. Everything that I have suggested can be accomplished without doubt with apparatus which is already available and is, to some extent, in use, but, of course, when a road of this kind is once established other improvements are sure to follow. We shall then have very fast trains, running over cheap roads on which it would be quite impracticable to employ steam, and passengers may then perhaps be taken from London to the sea-coast in 20 minutes.

Chas A Hague.

CHARLES ARTHUR HAGUE has been well known on both sides of the Atlantic for many years as a steam and hydraulic engineer. Of late, he has devoted particular attention to electricity for operating pumping machinery.

ELECTRIC PUMPING MACHINERY.

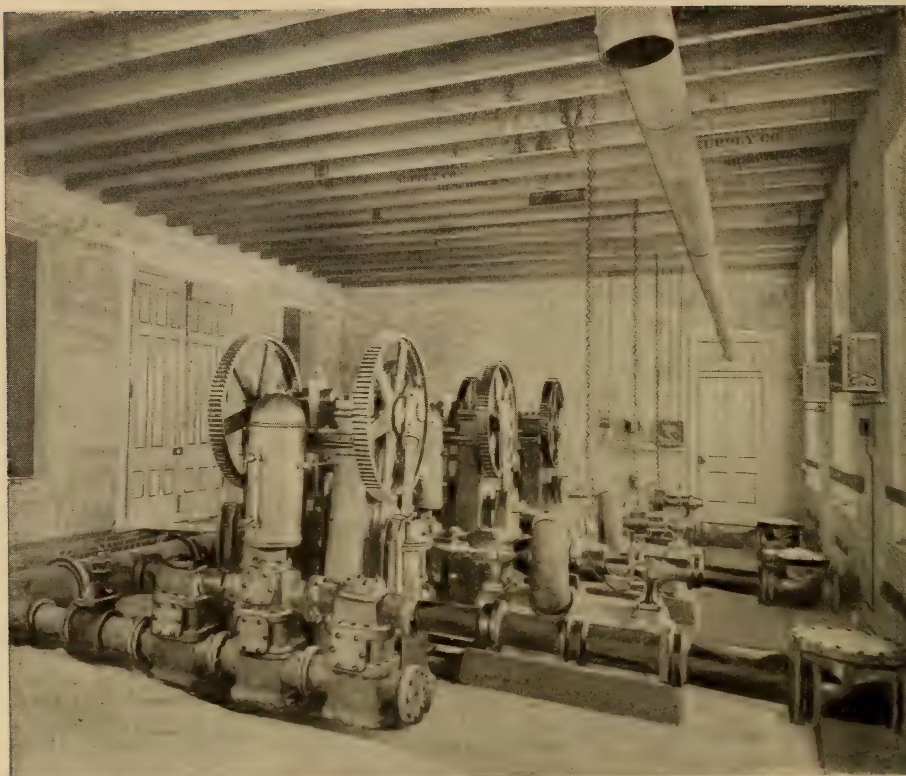
By Charles A. Hague.

IN the development and advancement of the methods of doing the world's work, none has been more rapid or striking than those represented in the application of the electric current to useful everyday effects. In noting this development in a rather practical way, it is neither necessary nor expedient to go back to the consideration of the fundamental laws relating to electricity and their discovery, to the art of producing, and the methods of utilising, the effects of electrical induction known to us as electro-dynamical currents.

The names of Ampère, Oersted, Arago, Volta, Faraday, Peltier, Joule and other school-book friends, come pouring in upon the mind, if we allow time to ruminate upon the progressive sequence which commenced in the early part of the century, and, at the present date, culminates in the electric locomotive and the electric pumping engine, and forces to the front the horseless, although not electrical, carriage, to say nothing of the many other forms of usefulness in which the effects of the electric current have been utilised, and to which we have become accustomed.

The transformation of the mechanical form of energy, represented by a falling body of water, or by the expansive force of steam, into the electrical form of energy, represented by the intensity and flow of the electric current, presents many interesting and attractive features to users of power generally, and just now particularly to those employing power for the purpose of pumping water ; and he who looks at the matter simply from a practical point of view, with the idea of elevating a certain quantity of water to a certain height, wants to know if the new school of power is, or is not, better and more economical than some of the older ones. By the school of power, is here meant, the mode of the application of the power directly to the work to be accomplished regardless of whence it comes ; as, of course, so far, in the absence of any available chemical production of "dynamic electricity," our old friends the waterwheel, and the steam engine, must be relied upon for the initial energy.

The relation between heat, energy, and electricity, is very close, however, and the gradual development of the chemical secret which shall make them easily and practicably interconvertible, is confidently awaited. The slow process of combustion, known as decomposition, in an electrical battery, gives out a current which seems to have all of the qualities and attributes possessed by a current induced by the rapid relative approach and recession of a magnet and a coil of wire, as employed in the modern dynamo driven by some tangible and measurable source of power. The work done directly by the sun is elevating by evaporation, and so providing the water of streams with potential energy, and the work done by steam, also derived from evaporation, through the agency of the active combustion of coal, are the



THE FIRST ELECTRIC MUNICIPAL PUMPING PLANT, SAN ANTONIO, TEX., U. S. A. THREE TRIPLE GOULDS PUMPS, GEARED DIRECTLY TO THREE C. & C. MOTORS OF 30 H. P. EACH.

two great practical examples of mechanical work convertible into the electrical effects, which we also derive from the lower form of combustion above referred to.

In considering the pumping of water by the power embodied in the electric current, that eternal law of nature, known under the name of economy, asserts itself and drives us to the task of securing the greatest possible results from the least expenditure of effort and material; hence, the question, now seemingly presented to the waterworks manager, of ascertaining whether or not this new mode of applying power to the work he has in hand, will pay to use; the fact that it is just now strongly asserting itself, breeding suspicion in his mind that it has come to stay, and that he had better look into it.

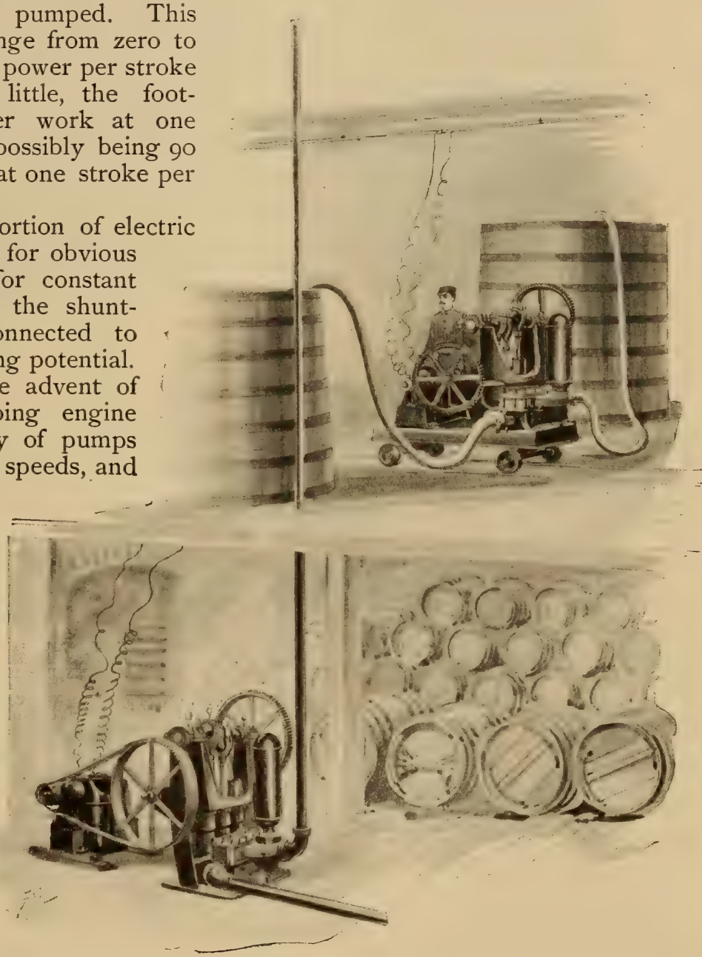
In very many applications of power, a great aim has been to maintain constant speed with variable power; and many excellent machines in the class of electrical motors have been produced with the constant speed object in view, however the load might vary. The shunt-wound motor, when receiving a current of uniform voltage, will maintain a constant rate of speed under varying loads, and will regulate automatically. Motors are also made in which the relation between the brushes and the commutator is regulated by a ball, or weight, governor, similar to that used in the regulation of steam engines as far as the adjustments are concerned, involved in the varying positions of revolving weights.

But in pumping water for public supply, a very large proportion of pumping engines must be operated at a varying speed and power, as in standpipe, or direct pumping service, as opposed to reservoir service wherein

constant speed and power are admissible. To still further complicate the matter, the horse-power per stroke of pump, varies by but a moderate percentage, for the reason that the static head of water in a reservoir service, or the mean pressure in direct service, constitutes from 85 to 95 per cent. of the maximum load, the variations in power being only those due to the variable quantities pumped. This variation may change from zero to full power, but the power per stroke will change but little, the foot-pounds of plunger work at one stroke per hour, possibly being 90 per cent. of that at one stroke per second.

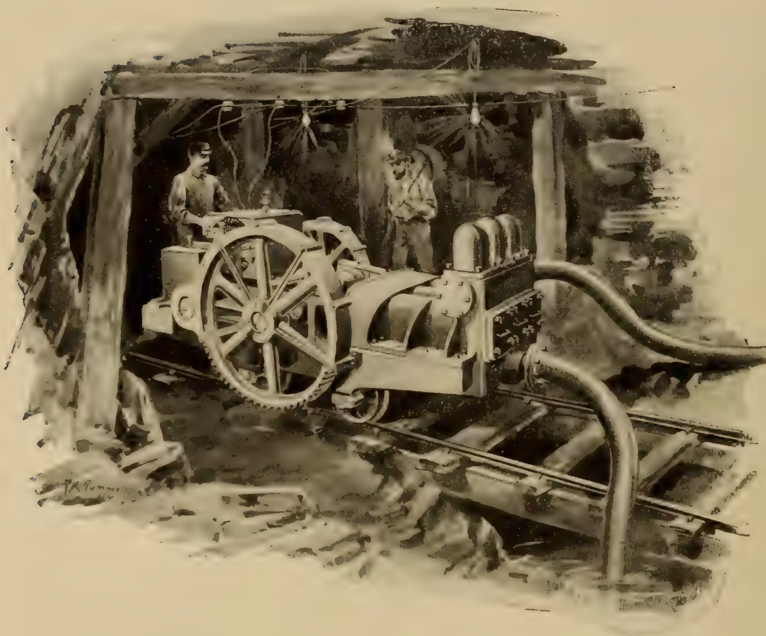
The larger proportion of electric motors have been, for obvious reasons, devised for constant speed, and are of the shunt-wound variety, connected to circuits of unvarying potential. Thus it is that the advent of the electric pumping engine found the majority of pumps working at varying speeds, and the majority of electrical driving machines arranged for constant speed. However, there is no reason to doubt the ability of electrical inventors to meet the demands in the application of the electric energy to the pumping of water under all of the varying conditions of pressure, speed and power, as is attested by the wealth of resources revealed in variable shunts, Wheatstone bridges, short and long shunts, variable speeds, constant speeds, distorted windings, combined shunts, constant and alternating circuits, etc., etc.

If other demands can be met, the type of motor doing away with the commutator, will, no doubt, prove to be the most practicable and desirable in operating pumping machinery, but if it is strictly an alternating current machine, it might do only for reservoir work, leaving a constant current machine for use in the field of variable power and speed peculiar to the operation of pumps under pressure.



GOULDS ELECTRICALLY DRIVEN FACTORY PUMPS.

The problem of pumping the main supply of water for a large city, by electrical means, is a comparatively new one, and although presenting many



A GOULDS ELECTRIC MINE PUMP.

attractive features as far as the actual operation of the pumping machinery is concerned, it is scarcely within the present possibilities on account of the absence of inexpensive methods of producing the necessary current apart from its development by well known means of power; and also by a lack of definite knowledge as to whether or not it will pay to generate the current by a steam engine or other means, and then use it at the pumping machine. Dismissing all ideas of producing the current chemically, or directly by combustion, the question arises, how can it pay to generate an electrical current by steam power for use in a second machine, when we can apply the steam power directly to the work of pumping?

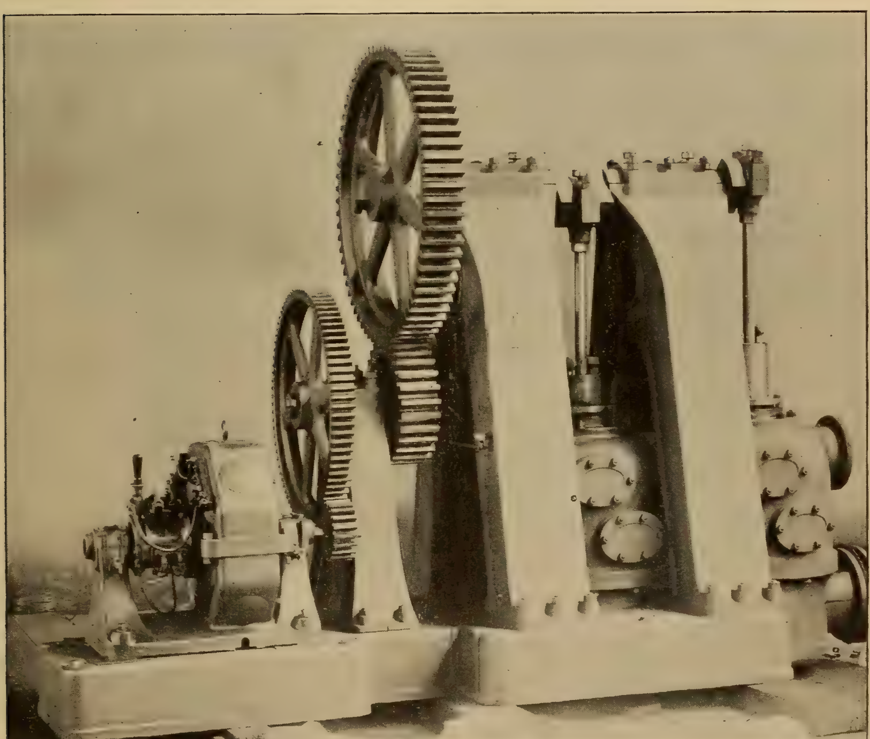
There are two answers at least to this question. One is, that by generating the current by means of a smaller, faster running and more economical engine than could be employed as part of a pumping engine, there might be enough saved in fuel, interest and maintainance of the steam engine portion of the plant, to more than balance any losses that might accrue from passing the energy through two transformations before using it; and this might come nearer to realizing good results in small and moderate sized plants than in large ones. The economy of the plant, to say nothing about convenience, could be still further increased by having the steam power and electric generator large enough to furnish current for other purposes as well, such as lighting, and also operating tools for a general repair shop for the department,—work which is often delegated to a second source of power.

With a 500 horse-power electric pumping engine, such as the author has in view in a general way, we may put the steam engine part of it at, say, 91 per cent. efficiency, that is the mechanical efficiency of the steam engine as shown by a dynamometer delivering the energy to an electrical generator, and as compared with the indicated horse-power; the efficiency of the electric generating portion at 95 per cent., which would be the percentage of the product of the volts and ampères leaving the generator, as com-

pared with the foot-pounds of the dynamometer ; the efficiency of a large, short copper wire, at 99 per cent.; the efficiency of the motor portion of the machine at 95 per cent., which would be the proportion of mechanical energy delivered, as compared with the electric energy received, by the motor ; and the mechanical efficiency of the pumping portion of the engine, which would be the pump horse-power as compared to the mechanical energy given out by the motor, at 89 per cent. Then the net efficiency of the electro-dynamic pumping engine would be in the neighborhood of 72 per cent., in terms of work done by the steam end of the machine. When the slow plunger speed of the every-day pumping engine is considered,—a speed to which the steam pistons are compelled to accomodate themselves,—the electric outfit would, in many cases, be able to move than hold its own.

If, in the higher class of steam pumping engines, in many cases handicapped by conditions of bad economy, the steam consumption for horse-power per hour should rise as high even as 16 pounds, then the thermo - electric pumping engine, in its ability to overcome the difficulties by reason of a faster and smaller steam factor, would very probably exceed its older competitor in practical every-day economy. This seems inevitable, excepting possibly cases wherein very great cost has been gone to in meeting unusually precise demands in construction.

The second answer to the question brings into the account some incidental items. Some of these pertain to water power, some to steam power, and some to both. First, as to water power, it is known to be erratic, or at least not reliable the year through ; and an important element comes into play in this connection at large water power loca-

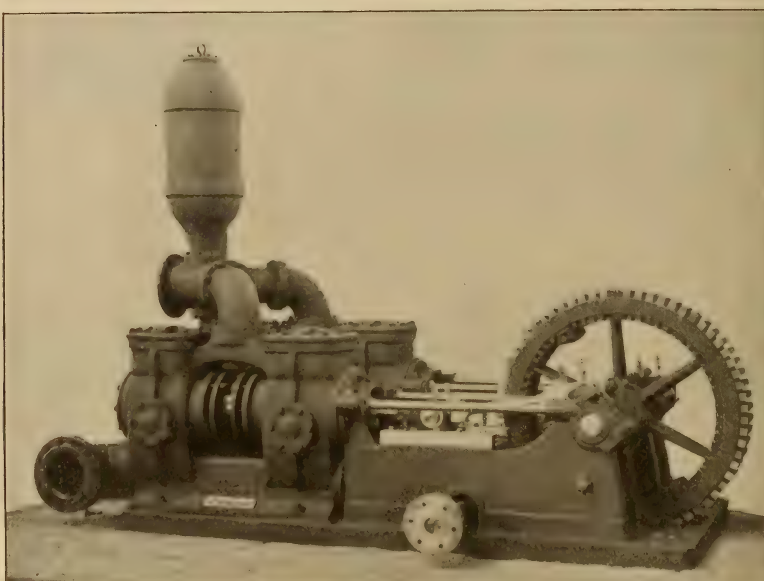


AN ELECTRIC WORTHINGTON PUMP.

tions, which electric light and power companies having currents to sell, no doubt are aware of and appreciate. That is the fact, that during the fall and winter months, when the demand for light in factories, shops and stores will give the light company plenty to do, the water in the stream is generally running to waste. In the summer, on the other hand, when many factories run the day through without artificial light, and the electric company is hunting for customers, the water supply is low, and scarcely of volume enough to run the factories.

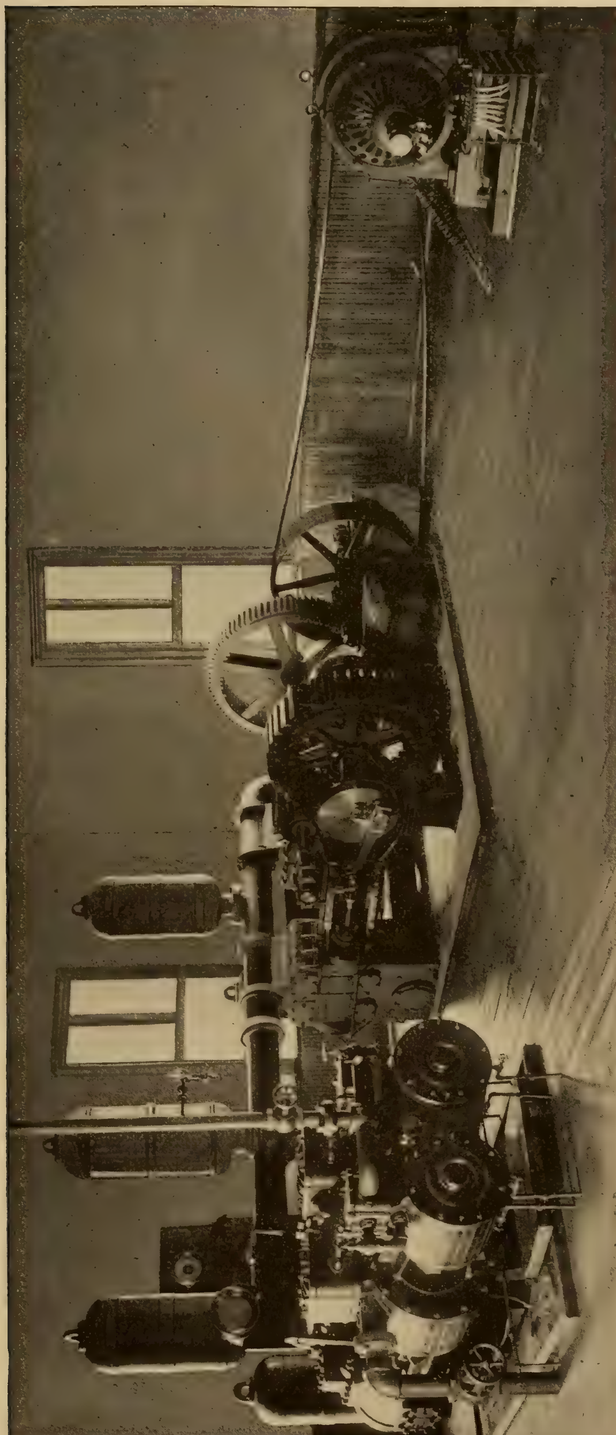
Now, when an electric generating company goes into extensive business, it must be prepared to meet demands at all times ; hence, under ordinary conditions, a large part at least of their power plant must be steam, and very likely it would be best exclusively steam, even in a water power locality as ordinarily understood. By this plan a double driving, and partly a double generating outfit, of several thousands of horse-power would be avoided.

In fact, the complication arising from the use of water wheel connections in plants in which it is desirable to use directly connected generators in large units of power, strongly dictate the exclusive use of steam, when it is considered, moreover, that the water can not be had continuously throughout the year, and also that the higher type of steam engine, in large powers, is extremely economical of fuel and attention. That is to say, if the circumstances forbid reliable water power all the year round, it would be better to have a perfect and thorough steam plant than a lame compromise of water and steam. It should be also borne in mind that new comers to water powers already pre-empted and owned, must pay pretty well even for water power.



A GORDON POWER PUMP FOR ELECTRIC WORK

A pumping plant of comparatively large capacity, near enough to the electric power station to receive power from it, could well afford to fit up its machinery so as to use water power when water was plenty and electricity scarce, and use electricity when the opposite conditions prevailed. Pumping twenty-five millions of gallons of



A 30 HORSE-POWER INDUCTION MOTOR BUILT BY THE STANLEY ELECTRIC MFG. CO., PITTSFIELD, MASS., U. S. A., DRIVING POWER PUMPS AT ANDERSON, S. C.

water a hundred and fifty feet high, requires only about 650 net horse-power, the elevating of water not ordinarily running into power very rapidly. It will be observed that the pumping station above cited would not only reap the benefit of buying electrical power when the market tended downward, but would do so just at the period when it needed the most power, and would also save the cost, interest, and repairs, upon a boiler plant, boiler house, chimney, all expense of storing, handling and firing fuel, and also save the cost of the fuel itself. Charging the cost, interest and maintainance of the water wheel and connections, against the above, there, ought, therefore, to be a balance in favour of the electrical outfit. The writer expects to be able to produce actual data upon the above sort of plant within a few months, that will be at least a step in the direction of finding out the facts as to the relative value and economy of electrical pumping upon a good-sized scale.

In the purchase of electrical power for pumping in places removed from water power locations, and where the current is generated by large steam plants for street railway and lighting purposes, several advantages to the water-works manager begin to appear. He saves the fixed charges and running expenses resulting from the owning of a steam-making plant and he gets the economical benefits of the mechanical handling and stoking of fuel which is rendered possible in the electric generating plants of the immense powers now becoming quite common—benefits not to be afforded in the restricted power and limits of the pumping station, as ordinarily found.

In a large city, however, with a pumping capacity of approximately three hundred millions of gallons daily, requiring in round numbers five thousand horse-power, a magnificent electrical plant of gigantic and ultra-economical possibilities could be established and maintained. There could be several generating plants, situated upon railroad lines, or accessible by water, so as to receive and handle fuel cheaply, and so that the smoke and dust would be far removed from the business and residence portions of the city. These plants could generate sufficient current for pumping the water and for lighting the city, bringing the fixed charges and the fuel accounts fully fifty per cent. below what they now are.

From the observations of the writer so far, he calculates that in many plants now operated by steam the pump owners can afford, between what they would save in fixed charges and what could be saved in fuel, to pay at least $75 (£15) per horse-power per annum. For example, there are many pumping plants now operating at about 200 horse-power and paying out $10,000 (£2000) or more per annum for fuel and labour in generating steam; the fixed charges against the ownership of the steam making outfit, added to this rate of running expense, easily carrying the cost of a steam horse-power up to and above $75.

Curiously enough, there seems to be a sort of balancing effect, tending to place large and small pumping plants upon an equal footing as far as buying electrical power is concerned. The small plant has low economy of fuel and a small amount of power with high proportionate labour account and fixed charges, while the large pumping plant, by its natural situation and power, comes within range of large and cheaply operated electrical plants.

The large steam generating plant, producing its steam energy in units of 500 horse-power or more; with its coal brought to it by water or by rail; the fuel elevated, conveyed, stored and sent to the boilers by machinery, either delivered upon the fire-room floor or into the hoppers of mechanical stokers; the thousands of horse-power of high-class automatic engines requiring no more actual labour of attendance than the few hundreds of a small plant; the extensive scale of economising the waste heat of the uptake; and with the feed-water of thousands of horse-powers of boilers handled by one steam pump, of a size admitting of the economical use

ot steam in its operation, possesses advantages for producing steam power at low cost *pro rata*, absolutely impossible of attainment by plants of small power and dimensions.

The initial power having been produced at the most economical rate possible with high-class automatic steam machinery in large units, its transformation into, and its transmission in the form of, electrical energy to where it is to be utilised, is possible with a very small percentage of loss. The efficiency of electrical dynamos and motors is very high, especially where machines of considerable capacity are employed. They are extremely simple as machines, very reliable, and capable of standing considerable abuse. For units of from 150 to 300 horse-power, from 92 to 95 per cent. of the energy delivered to them ought to be realised under good conditions; from 500 to 700 horse-power an efficiency of say 96 per cent., and for 1000 horse-power and upwards 97 per cent., and possibly 98 per cent.

Conceding that the operators of the large generating plant from which the water-works man is to buy his power, will adjust and carry the load so as to maintain a proper relation between units and power, thus realizing the highest efficiency at their end of the line, it would seem as though the electro-dynamic pumping engine could be arranged, if upon reservoir service, so as to maintain full load efficiency, and if upon variable service so that the total power might be made up of units available in proportion to demands.

A steam pumping engine cannot work to its best advantage at variable service, power and speed, and although the same sort of fate may await its electrical comrade, there are glimpses of possibilities with the latter, which are at least promising of better results than have even been attained with steam in cities and towns where the direct system of pumping is employed.

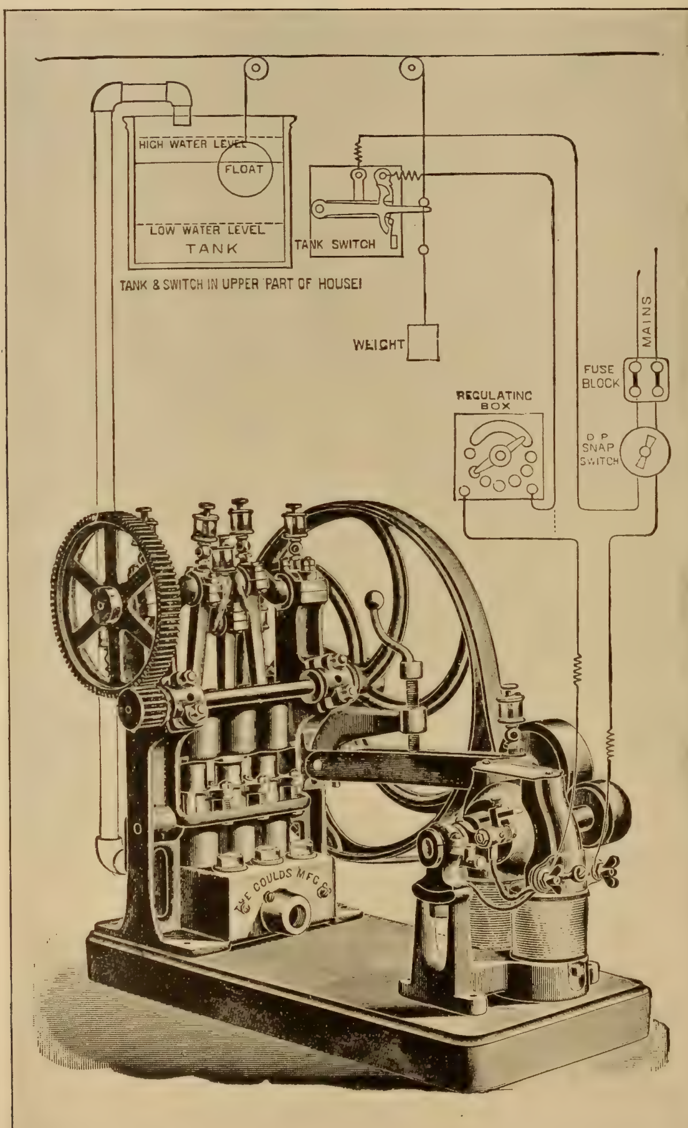
The convenience and controllability of the electrical mode of power, together with its simplicity of application to the work of pumping, particularly commends it for use in isolated plants, such as high-service systems comprised in those districts of a city not readily or advisedly included in the main distribution; also for outlying manufacturing plants consuming large quantities of water, and sufficiently near,—say within a mile or two,—to a source of water supply to render it practicable to run a wire from the main power plant, so as to operate pumps by electricity at their best point of location. The steam and generating machinery would then be under the care of the highest class of attendants, and would naturally be of considerable magnitude; while the electrical pumping machinery at the water side could be easily and safely attended to at small cost.

With reference to so-called high-service pumping for public water supply, the desirability of such service comes, of course, from the manifest advantage of pumping a comparatively small portion of the total supply against a moderate head instead of pumping the entire supply of the city against the highest pressure required to force water to the higher levels, where it is generally needed only for dwellings; and in addition to this gain, the main supply for the lower levels, embracing the manufacturing and commercial districts, is also furnished under considerably less pressure by dividing the service. The application of this mysterious mode of energy to the pumping of the main water supply of a city of considerable size, may be some distance in the future, but the science of electricity, although yet in its early days, has already advanced at a pace that has cast its shadow in a direction which certainly marks such pumping as a coming event.

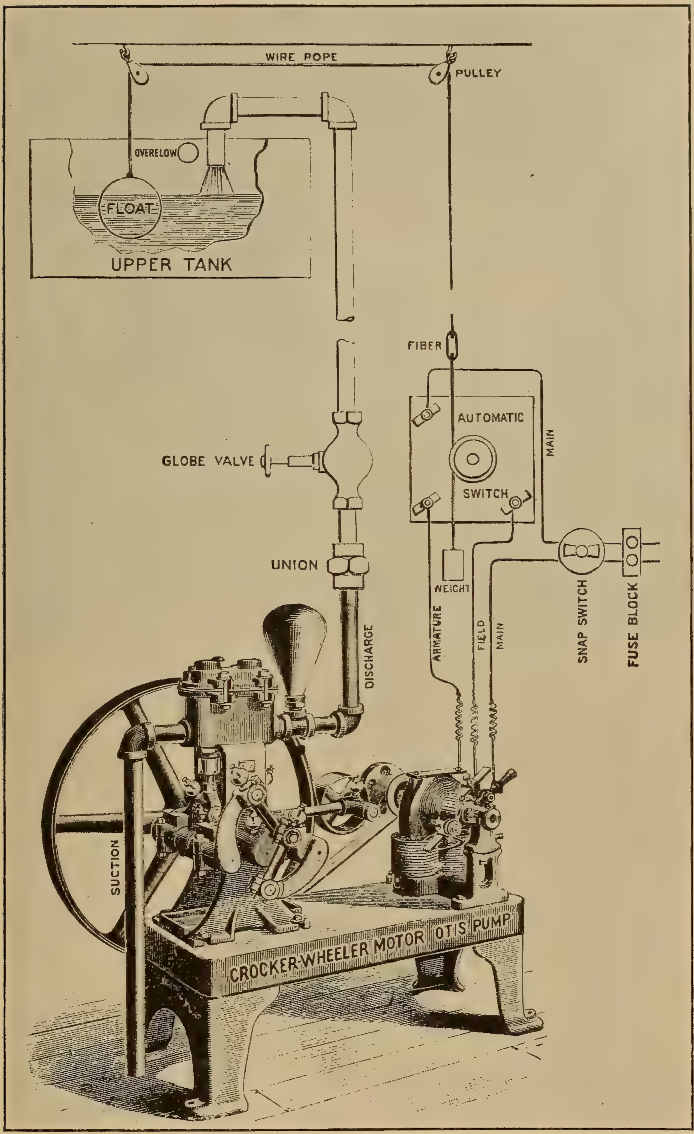
No one appreciates more completely than the writer, the valuable qualities of the high-grade steam pumping machinery produced to-day; but for all that, the assertion is confidently made that many large cities could, even now, pump their initial supply of water by a competently arranged electrical outfit, much more economically than they now are pumping, or could pump, it with the

best of steam machinery. The reason for this belief is that the electric current offers a long looked-for compromise between the slow moving and inelastic water at one end of the machine, and the highly elastic steam, requiring rapid motion, at the other end. The best attributes of the automatic cut-off engine are not possible when coupled to a pump plunger by rigid rods or gears, but the high efficiency and absolute elasticity guaranteed by the electric method, furnishes an arbitrator between two elements that have always disagreed.

To present the matter of high-service pumping in a practical form, and in familiar terms, exemplifying a useful

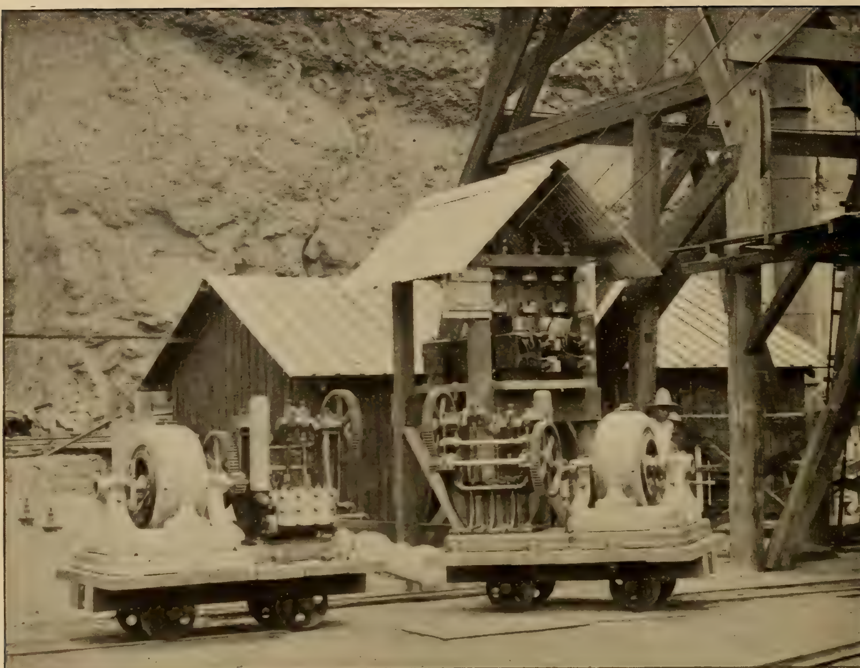


AN ELECTRIC HOUSE-PUMP OUTFIT.



ANOTHER ELECTRIC HOUSE-PUMP INSTALLATION.

employment of electric pumps to-day, let us suppose that the total supply of water for a certain city is 15,000,000 gallons a day, pumped at the initial station, and that 2,000,000 gallons are required for a district situated so high above the rest of the town, that it would be necessary to deliver the entire pumpage under a pressure of 125 pounds per square inch if the service were not divided; and that it would be necessary to deliver only the 13,000,000 gallons for supplying the main part of the city under a pressure of 75 pounds, were it not for the high levels. Then the difference in power required for supplying the city with and without a divided service would be as follows :—



A 20 H. P. TRI-PHASE TRANSFORMER STATION IN LOWER CALIFORNIA WITH TWO 10 H. P. PUMPS MOUNTED ON TRUCKS FOR WORK ON INCLINES.

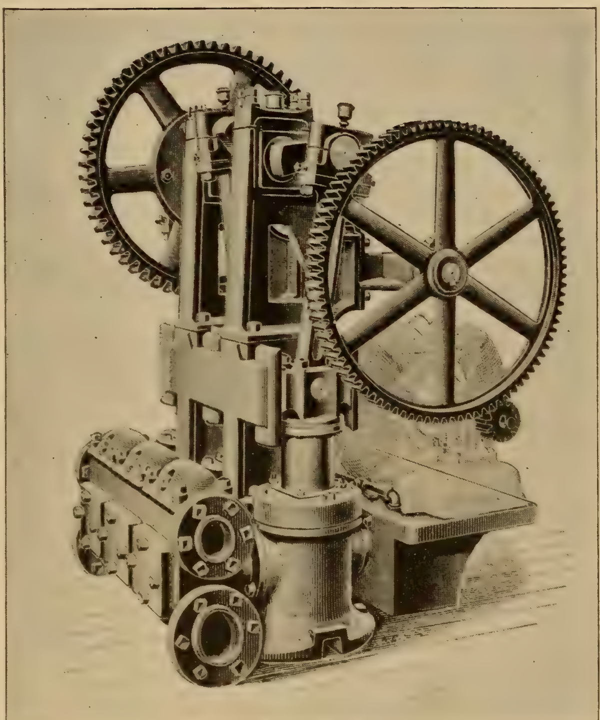
The total 15,000,000 gallons under 125 pounds load, delivered from the main station, would require 825 H. P. If the service should be divided, the entire 15,000,000 gallons would be pumped under 75 pounds pressure, requiring only 495 H. P., and then 2,000,000 gallons of this would be re-pumped against 50 pounds pressure for the high service, requiring 44 H. P. additional. This would make a total of 539 H. P. with the divided service, as against 825 H. P. with undivided service. The power saved would amount to 286 H. P., or a little over 34 per cent. The saving in fuel alone, per annum, upon a basis of 2 pounds of coal per horsepower per hour, would pay 15 per cent. upon the entire cost of a high-service plant operated by steam, and 27 per cent. upon a high-service plant operated by electricity.

The advantages of dividing such service are well known, and many cases can be pointed out, of well appointed plants for the purpose ; but the adaptability of the electric current to such work has not yet been realised to the extent extremely probable in the near future. If it were legally and politically possible, it would pay cities to contract their pumping to private companies, even now, by steam, and it would be possible to realise a large profit out of the saving in fuel and management. The dawning of the electrical era discloses still greater possibilities, but it is likely that the public must go on being punished, on account of the slow development of the equitable part of human nature.

It would be a very simple operation to generate the current at the main pumping station, with the steam plant used for the initial pumping, then run the wires up to a point best adapted for high-service operations, and there employ the electrically-driven pumps. Of course, a high-service steam pumping plant could be installed at the proper place, as is now done, but that would permit of no escape from ex-

pensive attendance, hauling and burning of coal, disposing of ashes, and last, although not least, the large quantities of smoke and dust dispensed broadcast over what is generally a residence district, much to the disgust of the owners of lawns and trees. The author has in mind now, a beautiful landscape, including drives, parks, expensive residences, and a lake-like reservoir. In the midst of the scene a huge chimney vomits forth, day and night, great volumes of black smoke and soot. If the housewives of that vicinity could be granted the right to vote, the electrical pumping engine would come rapidly forward for supplying that district at least.

Even if it should not be desirable to install an electrical generating outfit at the initial pumping station, power could be obtained from street railway and lighting companies already provided with electrical power in many cities. When we consider the inconvenience and cost of providing the various mains sometimes needed when all of the water for the upper levels is necessarily distributed from one central, high-service station, the possibilities of several electrical stations of moderate capacity, for separate districts, begin to hint at the economy in first cost and maintenance of such an electrical system. Water mains, 42 inches in diameter, and for say 75 pounds pressure, cost in place in the ground, approximately $1000 (£200) per inch diameter and per mile in length, the cost increasing slowly for smaller diameters, and decreasing for larger ones. The costs vary, if plotted, as indicated by a very flat hyperbolic curve; 24 inch pipe comes to about $1100 (£220), and 14 inch to about $1250 (£250) per mile per inch diameter. The market variations for metal and labour will affect the amounts somewhat, of course, but the relative values will remain practically the same, in any event showing that before additional lines of fairly large



A DEMING ELECTRICALLY DRIVEN PUMP.

pipes are laid to reach high-service points, it will pay to carefully look over the territory, now that the necessity of a boiler plant, buildings and chimney, are removed in many cases by the innovation of the already commercially successful, electrical mode of energy.

Coming events cast their shadows before. In the case of electricity, however, it was a case of casting its light before, instead of the shadow, early in the seventies, and we may see now how completely the forecast has materialised. Early in the eighties the Chicago Railway Exposition held within its walls

the embryo trolley car, with the incipient "broomstick," although not exactly in the present form. The exhibit was rather severely criticized as being impracticable, but its wonderful development has amazed even its most ardent advocates of that relatively distant time. The pumping engine may have the same experience. In the development of machinery and mechanical ideas, the present century apparently started upon the lower portion of a Mariotte curve, nearly level, but slightly inclined upwards; but the growth of the electrical mode of energy is enough to make one believe that we are now going up the steep part of the curve, soon to be moving in a nearly vertical direction.

The compound and the triple-expansion steam pumping engine for large capacities are, no doubt, now in full possession of the field, but there are strong reasons for believing that the hydro-electric engine will head off the quadruple-expansion steam machine before the latter will have a chance to fully develop. And in small sizes, it is extremely doubtful if the "high duty" compound steam pumping engine will ever appear in the face of the electrical possibilities.

If an economy of, say, two pounds of coal per horse-power per hour is ever to be realised in pumping 2,000,000 or less gallons of water per day by steam power, whoever is to do it will need to be awake and moving, or the electrical dawn now breaking will develop into a blaze of light, against which the direct application of steam to pumping water for waterworks purposes, will struggle in vain, and finally disappear. Already, for elevator service in large buildings, the tendency towards steam economy has taken the direction, where possible, of concentrating the pumping into one or at least, few machines, in which a larger unit of work increases the possibilities of better results. In waterworks operations fifteen years ago, a 10,000,000 gallon pumping engine was an exceptionally large one; but now, after passing through several stages of twelve, fifteen, and twenty millions capacity, thirty million engines are becoming quite frequent, and twenty million engines, quite common. There are just now, at least ten pumping engines of twenty million gallons daily capacity each, under contract for public water supply, one or two of thirty millions, several of twelve, and a number, at least as large as any of the above, under consideration.

The hydro-electrical engineer is sweeping the field with his telescope, and no one can easily foretell what another fifteen years may bring forth in the line of pumping machinery for public supply, for blast furnaces, steel plants, and other extensive purposes.

Park Benjamin

PARK BENJAMIN is a U. S. Naval Academy graduate, but resigned after several years of service to devote himself principally to electric patent practice. As a writer on engineering subjects he is widely known.

ON A LETTER TO BENJAMIN FRANKLIN.

By Park Benjamin.

THERE has lately come into my hands a letter yellow with age, which bears neither date nor signature. The writer begins with an expression of doubt ("If anything which happens in this foolish kingdom deserve your attention") and ends with the remark that certain persons, revealed only by initial letters, "will tell you who I am and how to direct to me." Its contents indicate that it was written in the fall of 1777. An endorsement at the bottom of its final page shows that it is "from Dr. Berkenrode."

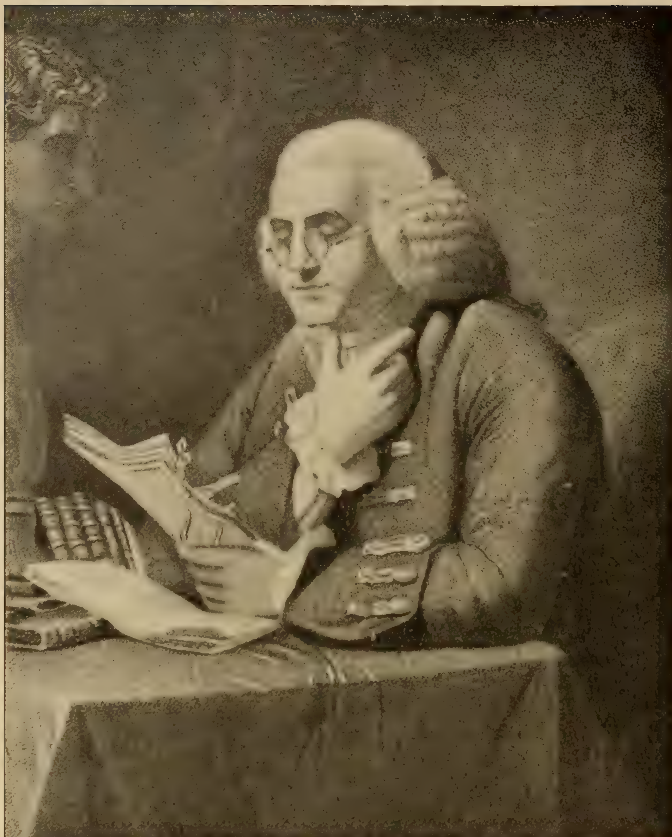
The recipient, in whose hand writing the endorsement is made, and from among whose papers it seems at some time to have strayed, was Benjamin Franklin; and it conveys to him the intelligence that his greatest discovery, which filled the whole world with wonder and admiration, has been discarded by his discarded King. "The pointed conductors on Buckingham House," it says, "are already taken down." Of the events which led to this communication, I propose now to tell the story:

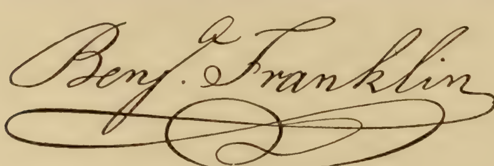
In the fall of 1748 Franklin retired from business in order to devote himself to the study of electricity. He sold his newspaper, almanac and printing house to David Hall, and, with a fortune sufficient to provide for his modest wants, turned from the cares of business to enjoy his long wished-for "leisure to read, study, make experiments and converse at large with such ingenious and worthy men as are pleased to honour me with their friendship or acquaintance."

The letters to Collinson, in which he had propounded his famous electrical theory and his analysis of the Leyden jar, had already been written. He was now advancing toward even broader conceptions, and the experiments which he and Kinnersley were making were multiplying the proofs and forcing upon his mind the conviction that the greatest conception of all was in fact well founded, and that lightning and electricity were one. Late in 1749 he recounts to Collinson the particulars in which the electrical fluid (as he terms it) and lightning agree, and among these he notes that the fluid of his jars and globes is "attracted and drawn off by points." It seems to him that if it can be shown that lightning also possesses the property of being attracted by sharp conductors, if it will come out of a cloud to a metal point as the electrical fluid seemingly comes out from the jar or the globe, then the fluid in the cloud and that in the glass must be identical.

At first he seeks to devise an experiment which will substantiate this idea, by an analogy. He tries to reproduce the conditions of the electrified cloud and the attracting point in miniature. After his simple and homely fashion, he arranges a brass scale-pan, so that it will swing over a needle placed beneath it and electrifies the pan. The experiment succeeds; the pan discharges on passing over the needle, and the most important of all his letters to Collinson is despatched.

In it is proposed the preservation of houses, churches and ships from the stroke of lightning, by fixing on the





ENGRAVED BY T. B. WELCH FROM THE PORTRAIT BY MARTIN, IN POSSESSION OF THE AMERICAN PHILOSOPHICAL SOCIETY.

highest points of them "upward rods of iron, made sharp as a needle, and gilt to prevent rust, and from the foot of these rods a wire down the outside of the building into the ground." The proposal is followed, with philosophic caution, by the question, "Would not these pointed rods draw the electrical fire out of the cloud before it came nigh enough to strike and there secure us from that most sudden and terrible mischief?" That is as far as he would then go,—a simple proposal and a query as to the results.

But there was less of the calm philosopher in Collinson, staid Quaker though he was. To him the idea "flamed amazement." He hastened to the Royal Society, of which he was a member, and laid the letter before it. The Society laughed at him. The whole notion was too absurd, too visionary for the trained minds which, at that time, were struggling with the intricacies

of human deformities and the delusions of "medical electricity." The rebuff only increased Collinson's determination that Franklin's letters should be published. He applied to Cave, the publisher of the *Gentlemen's Magazine*, and Cave, while refusing them a place in those dreary pages, at last after much deliberation, decided to print the collected letters in a separate pamphlet, with the understanding that all profits, which might be derived therefrom, should come solely to him.

Meanwhile, Franklin's electrical achievements were not only astonishing his neighbours in Philadelphia, but the fame of them had spread throughout the American colonies. His house was a rendezvous for curiosity seekers and invalids, the latter besieging him in the hope of gaining relief from the pangs of rheumatism through the powerful shocks from his cascade battery. Besides, the electric motor which he and Ebenezer Kinnersley had contrived was a wonderful thing. He had set electricity to work to turn a roasting spit, and there was also the "electric spider" and the "magic picture" and the "animated fish," not to mention many another odd conceit which the genial philosopher, who knew human nature so well, had devised to make the knowledge that he had gained attractive and easy to others.

During all this time, Franklin was puzzling how to convert his little laboratory experiment with the electrified scale pan into one of grander proportions, which would enable him literally to grasp the lightning. He saw no way of getting near enough to the thunder cloud. The discovery of the properties of hydrogen gas by Cavendish, which led to the first attempts at aerial navigation, was still in the far future. The meeting houses of the Quaker town had no pinnacles ; and, in fact, the whole province of Pennsylvania was without a steeple. He tried hard to revive the lottery which was to provide the funds to build a spire on Christ Church in Philadelphia, but the project, despite his efforts and influence, enlisted but little popular interest.

The summer of 1752 found the experiment still unmade and Franklin meditating a return to political activity. Then there came across the Atlantic, news which startled him. His printed letters to Collinson had fallen into the hands of the great French naturalist, De Buffon, whose master mind had not failed to grasp the import of the discoveries which they described, and who had immediately caused the book to be translated into French. The keen Gallic philosophers, ever on the alert for the curious and novel in Nature, had discussed the Franklinian experiments at their meetings, and the interest had grown until all intelligent people throughout France were talking of them. The King commanded the experiments to be repeated in his presence. The philosophers exhibited to him the strange contrivances which had already astonished the Philadelphians, but hesitated to attempt before him a trial of the lightning-attracting power of the pointed rod. That, they essayed in private, D'Alibard erecting an iron wire, 40 feet high, in his garden at St. Germain, and De Lor, a rod, 90 feet high, in Paris.

From both of these rods, sparks had been drawn during thunder storms, and people had received severe shocks from them. The intelligence gave to Franklin renewed vigor. He saw at once that these experiments, although on a greater scale than his own, were still inconclusive. The rods ended near to the earth. They did not extend to the thunder cloud—and in the latter he believed the lightning to lie. How was the cloud to be reached?

Then there flashed across his mind the idea of a kite,—of a kite which would carry his pointed rod into a low lying thunder cloud, so that if the lightning were electricity, it would come down to him on the kite string, just as the electric virtue from Stephen Gray's rubbed glass had run over hundreds of feet on a pack-thread line, and, better still, as Dufay had shown, thirty years before, over wet pack thread. So he made his kite, as usual out of the first things literally most conveniently at hand,—

his silk handkerchief and two sticks, placed crosswise and fastened to the handkerchief at its corners.

It was a square kite *—and not the coffin-shaped affair shown in the story-book pictures or in the omnium-gatherum badge of the American Institute of Electrical Engineers. To the upright stick of the cross he attached his pointed rod,—a sharp wire, about a foot long,—and provided himself with a silk ribbon and a key ; the ribbon, to fasten to the string after he had raised the kite, as some possible protection—how much he did not know—against the lightning entering his body ; and the key, to be secured to the junction of the ribbon and string to serve as a conductor from which he might draw the sparks of celestial fire,—if it came.

DR. FRANKLIN'S HISTORICAL EXPERIMENT IN THE SUMMER OF 1752.

FROM AN OLD ENGRAVING.

When the thunder storm broke, he went out on the open common near Philadelphia, and faced death,—faced the tremendous power of the lightning stroke, before which all people of all ages had quailed in terror ; faced what most of the world then believed to be the avenging blow of an angered God. True, he believed that electricity and lightning were the same thing, and therefore had no different properties or effects ; but he did not know it.

* I append an old engraving made early in the present century which shows the kite of this shape.

The best existing theory which accounted for electrical phenomena at that time was his own. The laws of electrical conduction or resistance, now so familiar, were not even suspected. Who could predict that the lightning would obey any law ? Besides, he had produced tremendous shocks with his Leyden jars in series, and had killed birds with them. More than that, he had been terribly shocked himself by the same means,—stunned into insensibility and nearly killed. He had said, again and again, that an electric shock, if strong enough, would blot out life, though without a pang. If his idea was correct, if his conviction was true, he was now about to face an electric discharge besides which that of the most powerful of man-made batteries would seem weak and insignificant.

All the world knows what happened. The kite soared up into the black cloud, while the philosopher stood calmly in the drenching rain watching the string, until finally he saw the little fibres of the hemp raise themselves. Then without a tremor he touched his knuckle to the key,—and lived. For the spark crackled and leaped to his finger as harmlessly as did that from his old familiar electrical machine, and allowed him to charge his jars with it with the same impunity.

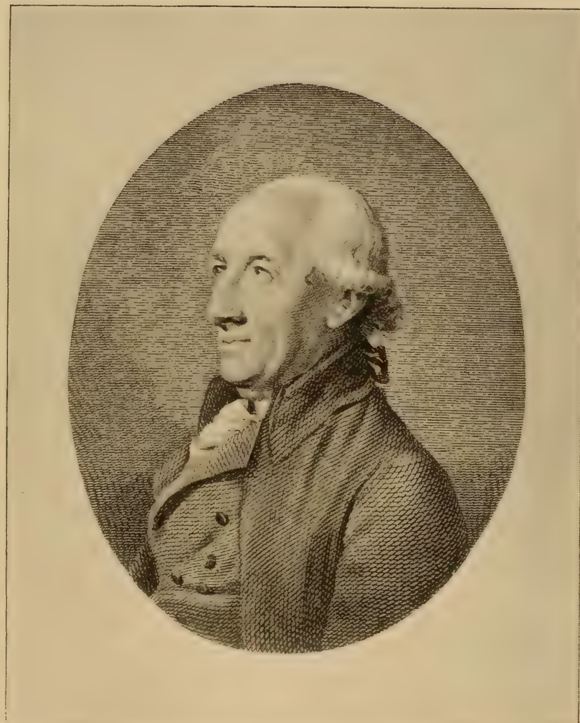
He sent the story of what he had done abroad, without a particle of trumpeting. He was not a discoverer for revenue. No stock markets awaited the announcement of his claims ; no newspapers stood ready to blare forth his achievement in the interest of the money jugglers. His own narrative barely fills one of the little columns of the *Gentlemen's Magazine* for October 19, 1752 (Cave meanwhile having graciously thought better of him), and it has at its end only the initials B. F. Conceive of a "modern wizard" retiring not only into such anonymity as this, but even failing to state that he had made the achievement !

"It may be agreeable to inform the

curious," begins this philosopher, so out of harmony with modern ideas, "that the experiment has succeeded in Philadelphia, though made in a different and more easy manner" from that followed by the Frenchmen. Imagine a "modern wizard" thus impersonal!

And the description is brevity itself. It would not fill the present printed page. It closes with the words, "From electric fire, thus obtained, spirits may be kindled and all the other electrical experiments be performed which are usually done by the help of a rubbed glass globe or tube; and thereby the sameness of the electric matter with that of lightning completely demonstrated." This is the way in which one of the grandest discoveries ever made by man was announced by the greatest philosopher and discoverer that America has ever produced.

Thereupon kites went up into the air over Charleston, over Turin, over Paris and over London. The philosophers of America, of Italy, of France and of England were following the newly blazed path. Here and there a rod showed itself over a roof, especially in Norfolk, Virginia. The people of Europe rose to excited interest, so excited that it alarmed the Church. The pulpits, when they did not fulminate against the awful impiety of seeking to ward off the chastening flame of the Almighty, anathematized the heretics who denied this same impious efficacy to the consecrated bells. But Galileo's rack was in the scrap heap, and no one feared the rekindling of Bruno's fagots.



DR. BERKENHOUT.

FROM THE EUROPEAN MAGAZINE, OCTOBER 1, 1788.

Then Franklin having his mind at peace through his great accomplishment, and seeing that Kinnersley, the

enthusiastic, was faithfully spreading electrical knowledge by giving lectures from Massachusetts to South Carolina, went back to his politics, and negotiated provincial loans in Boston, and tried hard to dissuade Braddock from his ill-fated expedition, and so pursued the useful tenor of his way, until the leading strings of the colonists began to chafe. And when at last "our gracious proprietary," as he once called the Penn owners of Pennsylvania, became oppressive, he threw his politics and his financiering and his electricity all to the winds together, and went to England to battle for the God-given rights not only of the people of Pennsylvania, but those of Massachusetts and Maryland and Georgia. When he got there the philosophers honoured him, and deemed it a marvel that such goodness could come from the American Nazareth.

While the presence of Franklin in England aroused renewed interest in his discovery, the lightning rod had by no means yet received the full sanction of the English philosophers. There was grave doubt concerning its efficacy. The great national edifices were unprotected by it. Worse still, there was an undefined fear of it, because of the death of the Russian philosopher Richmann, who had attempted to measure the strength of a lightning discharge coming over a rod, and had been killed in the attempt, owing to his failure to provide a ground connection. Its strongest English adherent was perhaps John Canton; but in 1762 he had turned to other investigations.

It was in that same year that intelligence arrived in England that the "Harriot" packet had come into New York Harbour, severely damaged by lightning; with her masts split, her boats stove, her compasses ruined, and her rigging burned. However much the British merchant might venture to risk his storehouse on shore, when it dawned on him that the lightning was a real menace to his commercial prosperity, through the peril in which it placed his ships, this was too sharp a touch upon his pocket nerve to be overlooked, and he soon acquainted the Royal Society with his desire for definite knowledge of the reputed new safeguard.

Dr. William Watson, easily first among English scientists of the day, took up the matter and proposed that ships' masts should be fitted with conducting wires, leading to the water, at the same time calling attention to some recent cases of damage by lightning to buildings, and especially proposing that the great powder magazine, then being erected at Purfleet, should be at once provided with lightning rods. Although the quantity of gun powder stored at Purfleet was large, this proposal met with no immediate response.

Two years later, the steeple of Saint Bride's church in London was struck and shattered, and a number of houses in Essex street were seriously damaged. Popular appeals to the Royal Society were renewed. The unexpected effect was to develop a new and bitter antagonist to the pointed rod, in the person of Benjamin Wilson. Wilson had been a house painter, and had become affluent through a contract for painting the government buildings. He studied electricity many years earlier, and, like most philosophers of his time, had evolved his own private theory to account for it. He had also written, in 1746, a treatise on the whole subject, which is apparently the earliest of its kind, and contains much misinformation.

The use of the pointed rod Wilson violently opposed, claiming that, so far from protecting buildings, it invited the lightning to them. He insisted that "the buildings should remain as they are at the top; that is, without having any metal extending above them, either pointed or not; and by way of a conductor, he proposed fastening on the inside of the building "a rounded bar of metal communicating with the ground." If the building had any iron vane or other ornament, he was willing that the rod should be connected to that. But, ultimately, his contention reduced itself to the essential requirement of a conductor

having a blunt or knobbed apex. The suggestion that the pointed rod actually invited the lightning to places where it would not otherwise go, proved to be exceedingly disquieting, not only to the philosophers, but to the anxious public, to whose already keen apprehensions the element of doubt was thus added. The Royal Society became at once rent into two hostile factions; one pressing upon the nation the urgent need of protecting its great buildings by the pointed rod; the other as strongly insisting upon the peril which would inevitably follow the adoption of such a course.

Meanwhile, Wilson had declared that the great Cathedral of Saint Paul was unprotected, and had advocated the use thereon of conductors erected according to his plan. But nothing was done until 1769, when the Dean and Chapter of the Cathedral, finding renewed cause for fear in still later injuries caused by lightning to buildings, formally applied to the Royal Society for an authoritative opinion as to the best mode of protecting the great church.

The Society appointed a committee, composed of John Canton, Edward Delaval (an electrician of some prominence), Benjamin Franklin, Benjamin Wilson, and Dr. Watson, thus including in it the foremost advocates of the opposing theories. All agreed that the Cathedral was in danger, that its many metal projections were not connected properly to the ground, and they pointed out the especial peril which menaced the stone lantern above the dome. The report, however, was a compromise, with a leaning towards the views of Wilson. It did not advocate sharp rods, but recommended large conductors to be connected to the already existing upward metal projections on the building. Thus the controversy was left practically unsettled.

Meanwhile the wars in which England had been engaged had caused an immense accumulation of gun powder at Purfleet. The fears of wholesale explosion increased. There was not only the danger of wide-spread destruction of life and property in the neighbourhood of the great magazine, but apprehension that the loss of so much powder might seriously impair the military resources of the nation. The Government then appealed to the Royal Society, and again a committee was appointed to consider the matter, the members being Henry Cavendish, John Robertson, Dr. Watson and Franklin. This time, Franklin went into the conflict with his whole heart, and exhibited to the committee experiment after experiment, describing them and presenting his arguments with that perfect terseness and clearness which, before him, had characterized the writings of Charles Dufay, and, after him, those of Michael Faraday.

To Wilson's objection that the pointed lightning rod invited lightning, he said:—"Were such rods to be erected on buildings without continuing the communication down into the moist earth, this objection might then have weight; but when such particular conductors are made, lightning is invited not into the building but into the earth, the situation it ends at." To the sneer of his opponent that his theory rested only upon "little" experiments, he replied that although pointed rods had been used in America for twenty years, only five of them had been struck, and that in every one of these cases the "lightning did not fall upon the body of the house, but precisely on the several parts of the rods, and, although the conductors were sometimes not sufficiently large and complete, went ever into the earth without any material damage to the building." His arguments prevailed and the committee formally recommended pointed rods.

Wilson attacked the report fiercely. He even twitted Franklin with the fact that, although he had been a member of the committee which had considered the protection of St. Paul's Cathedral, that committee had not specifically recommended pointed rods, thus trying to convict Franklin of inconsistency because the earlier committee under his (Wilson's) own influence had rendered a compromise report. But the new committee stood unmoved. It gravely

considered all of Wilson's objections, and then advised the Royal Society that it saw no reason to vary from the conclusions already expressed. Franklin's victory was substantial and complete.

The advocates of the sharp rod now took heart of grace, and, chief among them William Henley, by experiments as well as by the careful gathering of facts, demolished Wilson's contention thoroughly and in detail. The mooted question seemed to be settled at last. The pointed rods went up on the great magazine at Purfleet and on the king's palace.

Meanwhile the affairs of the American Colonies had reached a crisis. Great Britain had determined upon coercion. Franklin's efforts had failed and he left the country. His departure was the signal for the reappearance of the extinguished Wilson. Arguments which could not prevail against Franklin, the philosopher, might, he hoped, prove more potent when directed against Franklin, the rebel.

Fortune gave him his opportunity. In the spring of 1777 an unimportant building at Purfleet was struck. The damage was trivial, merely a few pieces of stone and brick being knocked off the coping of a wall. This was Wilson's chance. He insisted before the Royal Society that the pointed rods had utterly failed to perform their office, and demanded that they should be rejected as "threatening us every hour with some unhappy consequence." Then he played his trump card. "It is your very great concern," he says, "that I am obliged to take notice in this Society that a house which is of the first consequence in this kingdom has pointed conductors also fixed on it ; I mean the King's, our most gracious patron's and benefactor's," and without waiting for the Society's judgment in the matter he appealed over its head directly to George in person.

The Royal Society while yielding nothing in loyalty, had never acquiesced in the doctrine that the divine right of kings involved either omniscience or infallibility in matters of science. King Charles II. had destroyed the possibility of such a notion at the very outset of its career. It had neither forgotten the eager student of chemistry and willing learner who claimed for himself no more than the simple privilege of membership, nor the swift and stinging rebuke with which the King met its refusal to admit to its aristocratic company, John Graunt, tradesman. But it was a far cry from witty, cynical, intelligent Charles to slow, obstinate George.

Whatever the Royal Society or the American colonists or any others of his liegemen might think, George III., before all, considered himself as the father of his people and claimed obedience to him to be their first law. Failure to assist him could only be the act of "bad men, as well as bad subjects," and "assistance" meant acquiescence in whatever doctrines, opinions, theories or conclusions, political, scientific or otherwise, an inscrutable Providence might permit to find lodgment in his brain. At about this time he was hating Americans with especial fervor, and including everything American in the circle of his hatred.

The pointed rod was essentially an American idea, a seditious, rebellious, American conceit, and his sturdy British heart responded to Wilson's plaint so warmly that he and little Queen Charlotte and the Princesses all came to the Pantheon and graced by their presence the exhibition which was to bring confusion to the errors of the bad subject and exalt the truth as defined by the loyal house-painter.

The old letter before me tells what Wilson did. Not as fully, of course, as was afterwards recorded in the annals of the Royal Society, but with ample detail for the information of Franklin. There is, besides, a freshness about the narrative of the eye witness, which the dry official synopsis does not possess. Wilson was undeniably ingenious, and he was determined that his experiments, this time, should lack nothing in magnitude. He wanted a thunder cloud which would give, on demand, a lightning stroke ; but as a real cloud could not be conveniently

imprisoned in the Pantheon, he invented an artificial one.

He obtained from the Tower authorities a great number of drums, covered them with lead foil and bound them together in a huge cylinder 155 feet long, which he suspended by silken cords below the cupola. From the ceiling of the cupola to the drums, he carried, up and down, some 1600 yards of iron wire, each line of wire being kept apart from the other lines, so that the entire space between cupola and drums was thus filled. "All this," says the letter, "is intended to represent a thunder cloud,"—and it certainly is a very good imitation of one. The cloud was electrified from a double-cylinder frictional machine, and I leave Dr. Berkenhout to tell the rest in the words in which he told it to Franklin.

"Now as this cloud could not be made to pass with proper celerity over a house, the house is made to pass under the cloud. A wooden model of the Powder Magazine at Purfleet with leaden spouts, etc., is held by a loop at one end of a groove on a long table under the drums. To the other end of the house is fastened a rope, to the end of which hangs a weight, the rope running on a pulley. The cloud is then charged by twenty turns of the wheel, and a pointed conductor, of the same proportioned height with that at Purfleet, being placed on the house, the loop is slipped, and the house in passing under the cloud discharges it with a loud snap and considerable flash. The same being repeated with a conductor with a knob, the cloud is not infallibly discharged, tho' sometimes it is. Hence, he concludes that thunder clouds will generally pass harmless unless invited by a pointed conductor."

And the King was convinced. The pointed rod was not only a republican invention, but one expressly designed to injure his Majesty. He ordered it removed from Buckingham Palace at once, and the triumph of Wilson was absolute.

But the Royal Society remained ominously silent. "What the Royal Society thought of it I do not know," says the writer of the letter. The silence worried George. The members were his subjects, and his opinion should be their opinion. They might regard Wilson's show as clap-trap as much as they chose, but for them to differ from his conclusion was disloyal and intolerable. Whenever he was thwarted he was agitated, and this time his agitation was akin to that which he felt when Pitt, from his place in the House of Commons, rejoiced that America had resisted the Stamp Act.

He sent for Sir John Pringle, the President, and took him severely to task. The scene of Charles I. and the Speaker was re-enacted with variations. Sir John sturdily replied that he could only speak the sentiment of the Society which was adverse, and that scientific truth rested on fact and not on opinion. George dismissed him with a savage lecture, and, finding the Society still recalcitrant, stripped him of his office.

The letter meantime had found its way across the Channel, and was in the hands of the venerable plenipotentiary of the colonies to the French Court. One can easily imagine the amused smile which crept over his face as he read it. His comment is historical.

"The King's changing his pointed conductors for blunt ones," he said, "is a matter of small importance to me; if I had a wish about them, it would be that he would reject them altogether as ineffectual. For it is only since he has thought himself and his family safe from the thunder of Heaven that he has dared to use his own thunder in destroying his innocent subjects." Then he endorsed the name of the writer—which the writer had not dared to sign—at the end, and laid the epistle aside to await the outcome of events. They have all happened long ago.

Berkenhout, — not Berkenrode, as Franklin writes it,—remained a court parasite until he was sent to America in 1778 with the Commission for restoring peace to the Colonies, the intervention of which the Colonies con-

temptuously rejected. He was detained in New York but, surreptitiously making his way to Philadelphia, was implicated in an attempt to bribe members of the Congress, for which that body imprisoned him and finally shipped him back to England. "For having committed himself to the mercies of an Enraged Republican Congress," says his biographer, "his grateful country rewarded him with a pension."

Mr. Benjamin Wilson's knobbed conductors do not now rise above the dwelling of the gentle and gracious Queen, whose friendship for the posterity of King George's rebellious children has so often found timely manifestation. The Society which Wilson flouted in the sunlight of royal favour had its revenge in its recorded estimate of him which must stand imperishably. "It was by his obstinacy and improper conduct," says its historian, "that he introduced those unhappy divisions which had so unfortunate effect upon the Royal Society, and which were so disgraceful to the cause of science and philosophy."

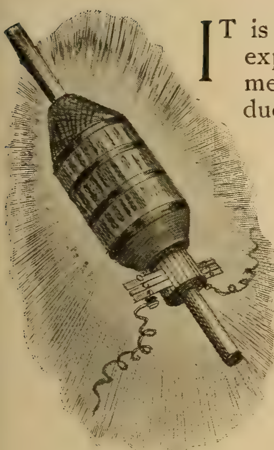
Such is the story which this letter of byegone days recalls. Of him who broke its seal, nothing can here be said which can add to the veneration and gratitude which he commands not only from his countrymen, but from all humanity. In these days of over-feverish activity, even in the quest of scientific truth, when invention is too often without philosophy, for which there is no room amid the jarring and sordid interests which prevail, it is good and wholesome to turn back to the doings of this American philosopher. He was our first,—he is still our greatest,—electrician.

Louis Duncan

DR. LOUIS DUNCAN is universally recognised as an electrical authority of the highest standing. The direct production of electrical energy is one of the subjects to which, of late, he has given special study.

THE DIRECT PRODUCTION OF ELECTRICAL ENERGY.

By Dr. Louis Duncan.



IT is best that I should first explain exactly what I mean by the direct production of electrical energy. There are many ways of producing it, and their relative directness is largely a matter of personal opinion and belief. The particular province of this paper is to consider the problem of obtaining electrical energy from fuel, in such a way that nothing is changed or used up except the fuel and the air required to oxidize it. Mr. C. J. Reed in an able discussion of a method suggested by Prof. Borchers puts the matter very clearly :—"The problem is the conversion of the energy of fuel (including fuel gases, such as carbonic oxide and hydrocarbons) into electrical energy by oxidation, without transforming the energy into heat and without the destruction of chemical reagents or the formation of waste products that require regeneration."

There are a great many indirect methods of obtaining electricity from fuel. The most familiar, as well as the most indirect, is the ordinary dynamo run by an engine which is supplied with steam from a boiler fed with the fuel. There are a number of transformations and the losses are excessive. From the energy of the coal we have a transformation into the energy of steam, then into the mechanical energy of the engine, and finally into the electrical energy of the dynamo. If we take all of the steam plants in the world, I doubt if the efficiency is 5 per cent.; we are wasting 95 per cent. of the coal used for power purposes.

Another method,—more direct but even less efficient,—is the thermo-electric battery, the action of which depends on the fact that if two dissimilar metals be joined to form a circuit, and their junctions be at different temperatures an electro-motive force is produced. Many such batteries have been built and some of them have even had limited industrial application, but their efficiency is so small and their depreciation is so great that they have never become a commercial factor. The reason of their inefficiency is plain. The thermal electro-motive forces produced by any practical difference of temperature are exceedingly small for any metals or alloys yet discovered, and this necessitates a large number of junctions and a long path for the current. To make the resistance small the distance between the hot and cold junctions should be as short as possible, and as it unfortunately happens that heat and electrical conductivity vary together a large portion of the heat flows from the hot to the cold junction and is wasted.

Lord Rayleigh, taking the thermo-electric constants of the metals usually employed, together with their heat and electrical conductivities, showed that the efficiency of a battery could not be greater than three or four per cent. In this case we transform fuel energy first into heat, then into electrical energy, and we find, as in other cases of the conversion, that it is difficult to get more than a very slight fall of heat potential in our apparatus and therefore we have a very small efficiency. As it is apparently impossible to transform any considerable percentage of heat into mechanical or electrical energy, it is of the greatest importance to skip this step.

There are other heat methods, some

of which have been tried on a comparatively large scale, but none of them give any promise of success. For instance, generators have been built which take advantage of the fact that at a certain temperature iron becomes non-magnetic. Turns of wire are wound around an iron core which is in a magnetic field, and which is so arranged that it may be heated and cooled. When heated above its critical temperature the iron loses its magnetism, the lines of induction which passed through it cut across the wire winding and an electromotive force is produced. When it is again cooled, the iron regains its magnetism and the lines of induction cut the wire in an opposite direction, again causing an electromotive force. Such an apparatus gives little promise of efficiency ; the limits of temperature between which it works are small and it has a small output for its weight.

Other methods have been proposed, involving the conversion of fuel energy into heat energy and then, more or less directly, into electrical energy ; but they suffer from this fact that when you have once obtained your energy in the form of heat, you can change only a small percentage into any other form ; the rest simply deteriorates.

In considering the subject of the direct production of electrical energy, there are three principal questions which should be taken up. These are :—

1,—Is it likely that the question will be solved?

2,—What will be the probable method of the solution?

3,—What effect will it have on the industries of the world?

As to the possibility of the solution of the problem, it would take a rash man to deny that in the future, some one, by accident or by reasoning based on a fuller knowledge of electro-chemistry, might discover a successful process. It does not take a very rash person to predict that some one will, and I am myself confident that it will be discovered. Many men, most of them poorly equipped for the work, have been engaged on the problem and some progress has been made. As for the method of the solution, it must be remembered that the problem is :—electricity must be produced and nothing but fuel and air must be consumed. This points to two methods,—either a gas battery must be used, or some substance must be discovered which will, in some way, convey the oxygen of the air to the carbon, without being itself decomposed.

Taking up the gas battery, many experiments have been made with it ; numerous combinations of electrolytes and electrodes have been used, but it must be confessed that the results are discouraging. Not very long ago it was announced by Dr. Borchers that he had made a successful gas battery, using carbon monoxide as the fuel, the electrolyte being cuprous chloride in hydrochloric acid, and the electrodes, carbon and copper.

Much discussion ensued and I am afraid that the result has been the dissipating of another dream of direct conversion. Further experiments have pretty clearly shown that the essential requisites of our definite conversion are not fulfilled ; other actions take place besides the oxidation of the carbon monoxide. The ordinary gas battery of Grove, in which two platinum electrodes, partly immersed in acidulated water, are surrounded by oxygen and hydrogen respectively, fulfills the conditions we have imposed in a very feeble way, and in an experiment of Dobrowolsky and Herding, ordinary illuminating gas and air were used to produce a current. In the latter case two carbons were coated with platinum black ; one was placed in ordinary illuminating gas, while the other was held in air, and, on being immersed in diluted sulphuric acid, and connected, a current was produced.

Gas batteries have never given practical results, nor have they, as a rule, fulfilled the conditions. In connection with this, by the way, some interesting experiments on gas secondary batteries under pressure have been made by Messrs. Cailletet, Collardean & Berthelot. Using palladium in a spongy state,

under a pressure of 600 atmospheres, a capacity of about 80 ampère-hours per pound was obtained, while the efficiency and discharge rate were very high. If we attempted, however, to make a primary gas battery on these lines, we are confronted by the fact that the action of the gas produced electrolytically at the electrodes is very different from the effect of the same gases surrounding them under pressure, while the cost of palladium and the pressure of 9000 lbs. used would argue against the adoption of the system for central station use.

If we consider the use of solid fuel in place of gases, we will find that many plans have been tried and a number of patents have been taken out. We often see in the daily papers that Edison or some other well known inventor has succeeded in solving the problem, but such announcements are never followed by performance. It is not so very difficult to oxidize the carbon. There are a number of batteries which do this, but the oxygen is usually taken from the electrolyte, not from the air.

In an early carbon battery of Jablochkoff, melted nitrate of potash, raised to a moderately high temperature, was used, and the oxygen was obtained by the decomposition of this nitrate. Other nitrate batteries have been evolved, but even if the electrolyte was not decomposed, the action, when it once begins, is too violent to be controlled. If the problem be solved with a solid fuel, the solution will be a simple one. It really means the discovery of the proper electrolyte. Of course, the carbon must be put in the form of a conducting mass, but this can be done for a small sum. I have experimented on a number of patented methods, but in almost every case either the electrolyte or the positive electrode was decomposed, usually both. Up to the present time, I know of no method that has been publicly described that fulfills the conditions or gives any promise of success. But I have seen a method, not patented yet, and unfortunately not mine, which does apparently fulfill the conditions, and which gives currents, measured not in mill-ampères, as is ordinarily the case, but in honest ampères, and plenty of them.

I do not think many people have thought about the possible effects of a successful direct conversion of the energy of fuel into electrical energy. Different industries will be affected in different ways, and to different extents. Some will be harmed ; will be practically done away with ; others will suffer indirectly ; others, again, will be benefited. It is one of the conditions of evolution that with every advance there is some corresponding suffering. It is a struggle in which we are raised on some one's shoulders, and for an advance which would be so radical there would be many victims.

Let us consider for a moment the generation of electricity for distribution from central stations. In looking over the expense account of a company supplying energy, say, for lighting, we are struck by the fact that the cost of fuel is a small part of the total running expenses, and at first sight it would seem that a process giving us 50 per cent. of the energy of the fuel would be no such great improvement over the present method, which gives, say, 10 per cent. We would use less fuel, to be sure, but the cost of the fuel, as stated, is comparatively small. If, however, we considered the total cost of the energy at the switch board terminals of the station, we can see that a simple process of direct conversion would make more than a small percentage difference in the cost. The generator would take the place of the boilers, engines and dynamos now in use.

If the efficiency of our present plant is 10 per cent., we are handling five times as much fuel, and our boilers are five times as large as they would be if the total efficiency were 50 per cent. If our direct method is comparable, say, to the generation of steam by a boiler, then, using it in place of our present system, would amount to changing our present plant,—boilers, engines, and dynamos, —for a set of boilers one-fifth as large. There would be no high temperature, no moving parts, no commutators to wear out.

Look over the expense account of a 1000 H. P. station ; subtract the wages of engineers, dynamo tenders and helpers, the cost of oil, supplies and repairs, all the expense, in fact, but a fifth of the fuel and enough men to run a 200 H. P. boiler. The result will be surprising, and it is a result which we may expect to obtain. For central station work, then, the decreased investment and the saving in operating expenses would so decrease the cost of production that there would be a great development in electric lighting, an industry now competing on equal terms with gas and needing no great additional advantage to drive the latter from the field.

I need not take up the question of distributing the energy, although the decreased space required, added to the simplicity of operation, would point to a multiplication of stations and a decrease in the cost of this item. For power distribution from a central station, the same conditions hold as for lighting. When, however, we wish to compete with an isolated steam plant the conditions are changed. Instead of substituting a direct generation for boilers, engines and dynamos, we must substitute such a generator and an electric motor for a boiler and an engine. In this case there is still a marked advantage in favour of electricity. Electric motors are usually much more convenient than steam engines, while the efficiency should be much greater than in the case of the steam plant. In fact, in every case where a steam engine is now used, we could substitute with advantage our method of direct generation.

In competing with water power, the two cases of the distribution of the power and its direct application are widely different. In the case of distribution we must substitute for the cost of the direct generator, the cost of the water power, of the development, of the turbines and of the dynamos. The cost of attendance may be assumed to be the same,—we are groping in the dark with respect to the attendance, on the direct generator,—and the cost of fuel must be added to the expense of the electric plant. Whether the interest, depreciation and repairs on the water power plant will more than counterbalance the fuel account of the direct converter, is a matter to be decided when the question comes up. I should imagine that they ordinarily would, and it must also be remembered that in the matter of distribution the location of the water power is fixed, while the converter may be placed in the most favourable locality—a matter of vital importance. Where distribution is not contemplated we must balance the direct converter and motor against the water power, its development and the turbines. Here, perhaps, is a case where it would be best to discard the direct generator, but even here it would depend on the cost of the water power development and the balance might still be in favour of electricity.

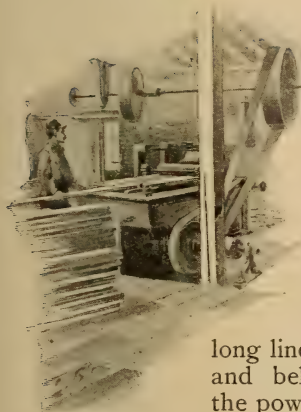
Finally, my conclusions are :— 1.—That the problem, as stated above, will be solved ; 2.—That the solution will be a simple one. I am unfortunately not permitted just now to describe what I believe to be one solution. 3.—That it will destroy the boiler and engine industries, and will seriously affect parts of the electrical industry ; but it will cause a development in applications of electricity, far reaching and helpful, in the end, to humanity.

R. E. B. CROMPTON.

R. E. B. CROMPTON was one of the first English engineers to become largely interested in practical applications of electricity for power and lighting, and since 1878 has built up one of the largest and most important engineering establishments in England.

ELECTRICALLY OPERATED FACTORIES.

By R. E. B. Crompton.



OF all the modern applications of electricity, probably none is of greater importance than its employment for transmitting power in factories; in other words, to take the place of the long lines of shafting, pulleys and belts, which distribute the power from the steam or water engine or other prime mover to the various machines which are to be driven.

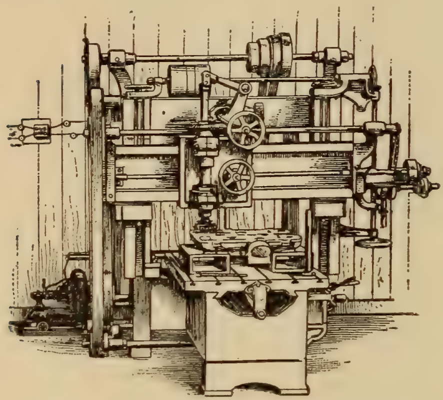
The advantages of electric transmission became evident from the first moment when it was noticed that with a current passing through a Gramme dynamo, the latter revolved and acted as a motor. Within a few years of this, almost every electrical engineer had developed this convenient arrangement wherever detached machinery had to be supplied with power at a distance from the main shafting. As early as 1881 the author supplied to M. Emil Bürgin, of Basle, a pair of dynamos to act as generator and motor for transmitting power at Schaffhausen, in Germany, and this early example of electric transmission, from which a combined efficiency of 66 per cent. was obtained, remained at work until the year 1890, in fact, until it was superseded by a larger scheme.

In this article it is not proposed to enter on the very extensive ground of electric transmission of power to great distances, but to consider the simpler problem of using electricity to take the place of shafting and belting for distributing power to machines in factories of moderate size, and in which the distances over which the power has to be transmitted do not exceed a few hundred yards.

The size and arrangement of factories, designed to manufacture goods in the most economical manner, is governed very largely by this distribution o power question. Whenever the old arrangement of shafting and belting has to be used, it matters not what is the source of power, whether steam, gas or water, the factories must be so laid out that the lines of shafting can be readily driven, either simultaneously or independently. This has hitherto been carried out in the most perfect manner by laying out all main lines of shafting, parallel to one another, by the very limited use of toothed gearing, and by the large use of belting or rope driving, as it is found that any arrangement of driving secondary shafting, at right angles to a large main line of shafting, through toothed bevel gear (although it appears at first sight to be a convenient one) is, in the end, noisy, wasteful in power, and costly to maintain. Even with factories so laid out, it is quite usual to find that on account of special processes which, by the rules of the insurance companies, must be carried out in detached buildings, transmission plant in the shape of wire or cotton ropes has to be used and such transmissions are, in many respects, unsatisfactory.

It was to meet the obvious inconvenience of transmitting power to detached tools which could not be readily placed in a convenient position to be driven from the main lines of shafting, or which required, from the above reasons, to be placed in detached buildings, that small plants of electric

transmission were first used, and there is no doubt that to the increasing employment of such detached transmission plants, originally put in solely for convenience, we owe the very wide development of electric transmission in



A VERTICAL MILLING MACHINE DRIVEN BY A C. & C. ELECTRIC MOTOR.

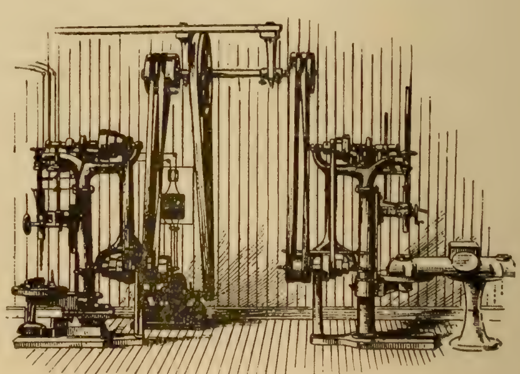
factories which has taken place during the last few years.

In fact, electric transmission, on account of the higher cost of the dynamos, conductors and motors, has not come into actual competition with the ordinary lines of shafting until a very recent period. This has been due to two causes:—1st, That the great economy attending the use of electric transmission was not at first noticed; and 2d, that the extended use of electric motors in cities where electric supply systems have been, for some years, at work, has so greatly increased the demand for them that special plant has been in many cases put down to turn them out in very large quantities and consequently at low prices, so that high cost of motors no longer is a deterring cause, preventing their wide introduction.

It is very evident that there are cases where a manufacture, such as that of explosives, must, for purposes of safety, be carried out in a number of detached buildings, and in such cases the employment of electric transmission is so evidently the most convenient and most economical system of supplying power, that its use has been almost universally adopted; but it is here proposed to show that, quite apart from these special cases, there are a very large number of factories in which the machinery can be operated electrically far more economically and conveniently than by the older methods hitherto in use.

The cases in which electric driving tells to great advantage are those in which the machines require to be driven intermittently. In these instances great economy follows, from the fact that no long lines of shafting are required to run idle during the time that the machines driven by them are kept waiting for the work to be fixed or for other causes. On the other hand, in textile or similar factories, where a steady amount of power has to be supplied to the machinery throughout the working day, and where the time that each machine is thrown out of use forms an insignificant fraction of the whole, the above advantage which electricity offers in reducing the idle hours of the shafting are but small, but even in these extreme cases there are economies to be obtained from electrical driving which make it appear probable that electricity may compete favourably with other sources of power.

Let us first take the case of a large



TWO VERTICAL DRILLS WITH A C. & C. MOTOR.

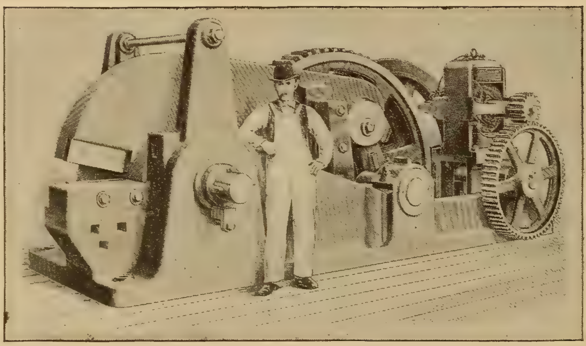
engineering works, such as is commonly met with in all countries where iron and steel is not only produced from the ore, but is also made into castings, forgings and finished engineer-

ing goods, steam engines, machine tools and the like. In such works, previous to electric transmission, we find the power required for the various processes which deal with the manufacture of the raw material, scattered over a large area. In the great majority of cases steam power is used; groups of boilers are put down at various points, each of which require the services of one or more stokers. Again, each group of boilers supplies a number of steam engines, some of them of large size, some of them small. The steam is conveyed to these engines by extended lines of steam pipes in which the condensation is very great, and each of these detached engines requires the services of an attendant.

It is needless to remind the technical reader that, worked under such conditions, the efficiency of an ordinary steam plant is excessively low. No one who has thoughtfully examined the power plant of the best arranged ironworks, either in England or on the Continent of Europe, can have failed to observe the extremely low duty that is obtained from the fuel in the form of horse-power actually applied to the work ; for, not only is the boiler efficiency low, but the condensation loss in the steam pipes is excessive, and the engines are worked so intermittently that there is no advantage obtained in compounding them ; and, further, the difficulties of collecting the steam from the scattered exhaust pipes entails such complication that, as a rule, the advantages of condensing cannot be obtained. In other parts of the same works, where the raw material is worked up and where the boilers and engines can be brought nearer to their work, the case is not quite so bad, but even there the power plant generally works at a low rate of efficiency.

To deal with such a case electrically is an easy task for the engineer. He has simply to provide a power house which need not be placed very centrally, but the site for which may be chosen for the purposes of the easiest and cheapest supply of fuel and condensing water, and for the most convenient attendance. From this power house he transmits energy exactly in the form in which it is required to every class of machinery that is to be driven in the works.

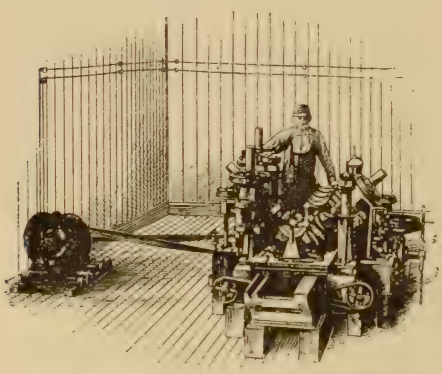
The author does not propose to select any special type of generating plant as preeminently suited for the power house of such a works. In every country we find direct-driving generating plant of high efficiency, and in all probability it is only necessary, for such a power house, to select such plant as that which is ordinarily used in a well-designed electric light station for the supply of light and power to a large town. It is abundantly evident that in these very large works, where many steam engines have to be used, electric transmission offers advantages almost as great as in the case of the explosives factories first mentioned.



AN ELECTRICALLY-DRIVEN SHEAR, BUILT BY THE FRANK-KNEELAND MACHINE CO., PITTSBURGH, PA., U. S. A.

We now come to the most common case,—a factory of moderate size, where the buildings are of such dimensions that the shafting can be driven by not more than two or three steam engines, conveniently placed, and where the work is such as that of building steam engines, or general mechanical construction.

It is necessary here to digress a little, to point out the various methods of employing electric motors for driving machinery. In order that we may obtain the fullest economical advantages from electric transmission to machine tools, we must, as far as possible, do away with shafting and belting by supplying an electric motor to each machine, so that whenever the tool is not doing useful work, the motor is completely at rest and no electrical energy is used. This, the most perfect system, has hitherto not been adopted to its fullest extent on account of the high cost of small motors, so that, in the



AN ELECTRIC SPECIAL MILLING MACHINE.

majority of cases, it has been found cheaper to forego some of this advantage and to group several small machines, connecting them by a short line of shafting which is driven by a motor.

This arrangement which, at first sight, appears to be far from perfect, is not so imperfect as it appears, for the reason that with the modern system of manufactures such small tools are driven, doing useful work, for a very large share of their total time. This is due to the extended use of jigs and like apparatus for the drilling machines which enable the driller to keep his machine almost constantly running, or to the use of special stops, combined with capstan rests and similar appliances in the smaller sizes of lathes which are usually employed for turning or shaping small articles.

At the same time, the reduction in the cost of small motors is going on at such rapid rate as to make it probable that, at no distant time, it will be found an advantage to supply each of these small tools with its own motor; but even at present time, in electrically operated factories, separate motors are, in actual practice, supplied to all the large tools and to a very considerable number of the medium size tools, especially to drilling machinery which can be made portable and so be carried to its work instead of making it necessary to carry the work to the tool. The work, it must be remembered, is, in some cases, very massive and costly to move.

Factories in which the whole of the plant is operated electrically to the above extent are now becoming common, and from some of them it has been possible to obtain data which enable us to show with great confidence the very considerable economy which such electrical transmission offers.

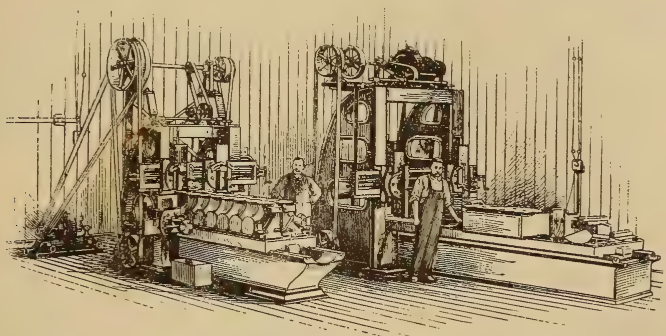
Although Professor Kennedy, the president of the Institution of Mechanical Engineers, of England, in his address to that Institution in April, 1894, considered that in a factory, with the useful work taken at 100, the total I. H. P. of the steam engines may be taken at 145, the author finds that this proportion is far too favourable and is true only in the case of a limited number of establishments where the load is steady throughout the working day. In most cases the following figures more closely represent the actual state of affairs :—

Average useful work	100
Average wasted in belts and shafting	75
Average wasted in engine friction	60
Total average I. H. P.	235

If the author's assumption is approximately correct, and he believes it to be so in the majority of cases in works such as we are now considering, and if we apply it to a factory which requires an average of 500 H. P. net, delivered at the tools, we find that the average I. H. P., which probably would be spread over three steam engines, would be 1175. We find, however, that in order

to work this plant for 2950 hours per annum, taking coal at 12s. a ton, the coal bill would work out at £2260 ; the probable wages bill, £1480 ; the stores, £600, and the repairs and depreciation annum per net H. P., which is exactly half the cost of the older system.

It will be seen that a very large share of the above saving is on the labour bill and that consequently, in the cases



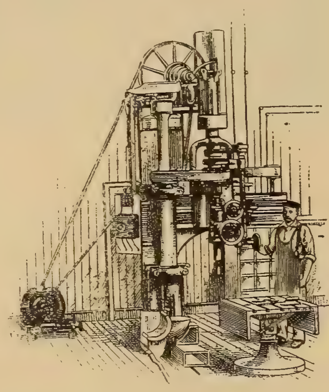
A C. & C. MOTOR DRIVING TWO PLANERS.

of plant together, £1600 ; making a total cost per annum of £6000 for 500 net H. P. delivered at the tools, or at the rate of £12 per annum per H. P.

Now, what can we promise by substituting for this arrangement a modern electrical equipment? In the first place, although we should still divide our total power between three engines, we do so only in order to avoid the risks of a breakdown affecting the whole establishment. We should make these three engines identical in form and size and we should place them together so that they could be worked by one attendant.

We can claim for modern generating plant that it can be made with certainty to specification to produce the electrical H. P., delivered at the terminals of the various motors, distributed all over the works within a radius of 500 yards, with a consumption of 2½ lbs. of coal per hour, and it is easy to show from the actual records of Messrs. Siemens, Messrs. Crompton, and others, that the proportion of useful work done at the tools may bear to the average I. H. P. of the engines the high proportion of 500 : 680, so that the total coal bill in this case would be only £1080 ; wages, £375 ; stores, £260 ; repairs and depreciation, £1300, making a total per annum of £3000, or £6 per

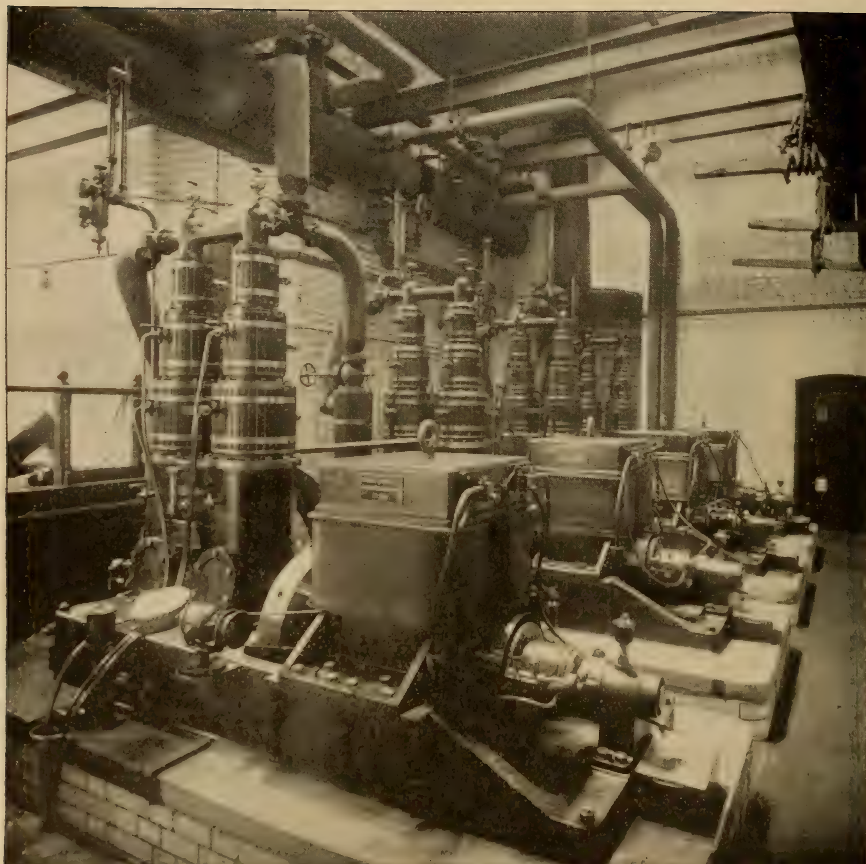
where fuel is exceptionally cheap, the saving would be diminished ; but even if we take fuel at the extremely low price of 6s. per ton, the correction in the above figures would be only such



A RADIAL DRILL WITH A C. & C. MOTOR.

as to reduce the cost of the older system to £10 per annum per net H. P., and in the case of electric transmission, to £5. In this case, too, it is here shown, the saving effected may be £2500 per annum.

This large margin, which can be well established from the very careful data obtained by Messrs. Siemens in a long series of trials at their works, and by



A STATION WITH DIRECT-CONNECTED WILLANS ENGINES.

Messrs. Crompton in a similar series of trials at their works, could be probably obtained, though, of course, to a small extent, in cases where the machinery is much more regularly driven, as, for example, in making textile fabrics. The author believes that it is not at all a difficult matter to take the cases of a large number of textile factories, which have been fitted up recently to be operated by rope driving with the least possible transmission loss and at the least possible annual cost of upkeep, in which electric transmission could be substituted and a saving shown, but these cases, although interesting, are those which the electrical engineer is least likely to be called upon to deal with.

Apart from the economy in cost of power which can, in most cases, be shown to follow on the adoption of electric transmission, it is necessary to point out its great convenience. However ingeniously the belt driven gear of machine tools is contrived, it is always difficult to keep the shafting and belts clear so as to avoid interfering with the lifting appliances in these factories. No such difficulty occurs in the case of electric transmission. In all larger tools the electric motor should form an integral part of the tool itself, and the conductor can be carried to it in such a manner as to be completely out of risk of interference with the gangways or the floor or with the lifting appliances overhead.

In modern factories, where large masses of material have to be dealt with,

there are many cases where the moving about of a heavy casting or forging is, if possible, to be avoided ; it is far more economical to bring the machine tool up to the work than to move the work up to the tool, and this is readily carried out with electric transmission. Drilling, shaping and milling machinery can be made portable and can be brought up and fixed to the work by the ordinary shop lifting appliances. As soon as such a tool is in position, power can be applied to it from distribution boxes, arranged at convenient intervals along the floors or walls of the workshop.

In this way the floor of a large erecting shop can be kept entirely free from obstacles or hindrances of any kind, so that large pieces of machinery of any class may be erected in the positions most convenient for them, and any machining to be done on them can be carried on by the tools being brought up to them and operated electrically. It can be easily shown that in most cases such an arrangement will lead to the reduction of the total number of tools required as well as in the cost of doing the work.

Further than this, the introduction of electric power all over a mechanical work shop is attended with many advantages which are now only commencing to be appreciated. Not only can welding, brazing, soldering and many similar operations requiring high temperatures, be effected by electrical means in a most certain and economical manner without oxidation of the surfaces, but annealing, case-hardening and other operations can be effected locally to parts of a structure, and results can thus be produced which were quite impossible before the introduction of electricity.

The author does not propose to enter into any lengthy comparison of the various systems of electric transmission that are in use. In many cases the electric transmission plant has been developed from the electric lighting plant originally put down for lighting the works, and in such cases direct-current electric motors, worked at from 100 up to 200 volts, have been found highly satisfactory. The only improvements which could be made in the use of these motors has been in diminishing, as far as possible, the slight attendance required at the commutators and brushes, and the necessity for occasionally oiling the bearings. This has prevented direct-current motors from being placed in inaccessible positions, but, of late, the use of multiphase commutatorless motors has enabled them to be placed in comparatively inaccessible places, and now, that the use of self-oiling bearings, containing oiling rings, has become so universal, such motors can be run for many days without attendance or even inspection.

The author noticed quite recently, in several of the large Swiss engineering works in which electric transmission is used, that a favourite position for these commutatorless motors was inside the built-up wrought iron supports which carried the roof and travellers. This is a very neat and convenient arrangement, placing the motor, as it does, out of all possible reach of injury. These commutatorless motors are also frequently used for driving tools of the planing machine class, and are then placed out of reach under the level of the workshop floor. Some very well arranged examples of this, in which multiphase motors are employed to drive planing machines by worm gearing, may be seen in the Oerlikon Works in Switzerland.

Although multiphase motors have this considerable advantage of requiring so little attention, yet against this must be set the necessity of carrying three conductors everywhere, with corresponding complications in the switching arrangements. Moreover, the direct-current system has the advantage that the same generating plant can be used for the supply of light and power and also for welding, annealing and similar purposes which cannot be nearly so readily carried on when alternating currents are used.

Although the author has said little about the best form of generating machinery to be adopted wherever the energy is supplied from a central situa-

tion, i. e., a power house, this article would be incomplete if it did not indicate to some extent what the author believes to be the best practice as regards generating plant. In England the experience of the last ten years has been to show that the highest results in economical efficiency, combined with low first cost of plant, has been obtained by the use of high-speed, direct-acting engines of the Willans, or similar, type, coupled directly onto two or four-pole dynamos.

Such plant has been largely used for central station electric lighting purposes, for generating electricity for metallurgical purposes, and also for the power houses of works. There are many cases on record where such generating plant is run continuously all the year round; that is to say, it is started up on New Year's day and is run night and day without stopping the engines or dynamos, until the following Christmas day, the Christmas week being occupied in cleaning up and preparing for the following year's run. In such cases, where the power is supplied for 24 hours, the electric H. P. has been produced with this class of machinery at 9.225d., and it is believed that this cost can be still further reduced to 0.19d.

It will be seen that at this price the production of energy for distribution throughout the works compares very favourably with the lowest cost at which energy has been distributed where water power is the prime mover. This results from the fact that the interest and depreciation on the capital invested is so much lower in the case of the steam plant than in the case of the water power plant, and this difference is sufficient to compensate for the whole cost of the fuel used by the steam plant.

In the ordinary cases, where the plant is not driven night and day, but only during the working year of about 2950 hours, such low figures cannot be obtained, but it is quite possible to approximate to them very closely, and to those who wish to operate their factories electrically in the best possible manner from an economical point of view, the author can only recommend them to use in their power houses plant of this description, which has stood the test of several years' running and yielded such extraordinary results.

When such generating plant is used, and under the ordinary distribution conditions, where the most distant machines to be driven are situated not more than 500 yards from the power house, there appears to be ample evidence to show that there are a very large number of cases in which the highly favourable results given above can be reproduced with certainty, and that consequently the field for this employment of electrical energy is very large indeed, and will doubtless soon be generally appreciated at its full value.

J. S. Robertson.

JAMES SMITH ROBERTSON is well known as a newspaper man both in Canada and the United States, and has contributed extensively to a number of engineering periodicals. He has more particularly devoted himself to the electrical industries, of which, so far as they concern Canada, he writes in this number.

ELECTRIC POWER IN CANADA.

By J. S. Robertson.

PROGRESS in electric lines in Canada, as elsewhere, has been largely in recent years. True, the telegraph takes us back to the forties, and, with a remembrance of one's boyhood days, are mingled stories of the witch-like methods then extant, enabling soul to communicate with soul, though hundreds of miles apart. No novelty, however, attaches to the telegraph to-day, nor are the superstitions of those times more than a tradition.

In some respects Canada occupies an historic position in the electrical world, not only in the telegraph, but in the telephone, the electric railway and electric lighting. It was in this country that Professor Alexander Graham Bell made his first experiments with the telephone, and that some of the earliest experiments in electric propulsion found their home. But particulars of these as we proceed.

Canada is peculiarly and favourably situated for the development of electric power in her magnificent water powers, located in different parts of the Dominion. Everyone, I fancy, has heard of the water power of the Chaudière, at Ottawa. In the Lake of the Woods district, near the dividing line between the Provinces of Ontario and Manitoba, is the magnificent dam of the Keewatin Power Company, favourably located and constructed for the transmission of electric power, either for use for industrial purposes in the

CHAUDIÈRE FALLS AT OTTAWA.

district or for distant transmission. The question of transmitting power from Keewatin to the city of Winnipeg, a distance of 160 miles, is already under consideration and does not seem impracticable. After the invaluable Niagara issue of CASSIER'S MAGAZINE there need only be a reference to the power stored up in that historic district, and which must in the near future work electrical wonders in both Canada and the United States.

We will, perhaps, grasp more intelligently the actual development made in electrical affairs in Canada if we divide our story into heads. In doing this one must necessarily start with the telegraph. Here, as elsewhere, it has been the pioneer in the utilisation of electricity.

The beginnings were small. Where to-day the wires of the Great North Western Telegraph Company and those of the Canadian Pacific Telegraph connect every village and hamlet, as well as the larger towns and cities, one with the other, this position has been attained only after years of hard pioneer work and many a severe struggle. The Montreal Telegraph Company, which was a familiar name in Canada before the present concern became owners of it, and the Dominion Telegraph Company, uniting the two under the name of the Great North Western Telegraph Company, was formed in July, 1847, and during that year a single wire was constructed from Montreal to Quebec and to Toronto.

We realize very clearly sometimes the blessings and opportunities of the present by a comparison with those enjoyed by our forbears. Apply this rule to telegraphy in Canada and the progress has been marvellous. The receipts for August during the first year of the Montreal Telegraph Company, for the entire line, averaged £7 per day, the calculation in those days being in pounds, shillings and pence, rather than currency. Fifty dollars a day, we are told by a local historian, was the average then ; 30 years later it was $1750.

Take another way of marking progress. In a single room, on what is now Front street, Toronto, with a solitary operator sitting on his high stool and labouriously spelling out from his register paper the messages that came over his single wire from Buffalo or from Montreal, the telegraph business in that city and district was done. This was in 1849. Mr. H. P. Dwight, the general manager of the whole system of telegraphs in Canada, now operated by the Great North Western Telegraph Company, was that solitary operator. To-day he is the head of a system whose receipts run into large figures, and whose wires, in length, are to be counted by the thousands of miles.

During the period between 1847 and the present date the telegraph in Canada, viewed commercially, has had its ups and downs. Rival companies were started at different times, the most prominent of these being the Dominion Telegraph Company, established about 1871, and having 490 offices and about 9000 miles of wire in 1880. But with the collapse of its United States connections it was eventually bought up by the Western Union and merged with the Montreal Telegraph Company under the name of the Great North Western Telegraph Company.

The business to-day is divided between this company and the Canadian Pacific, which is one of the various adjuncts of the Canadian Pacific Railway. This has been remarked of the telegraph in Canada, as I shall have occasion to say of the telephone, that in proportion to population there are more telegraph offices in Canada than in any other country, and the telegraph wires are more used there, as shown by the number of messages per head, than in France and Germany, and a very little behind the United States.

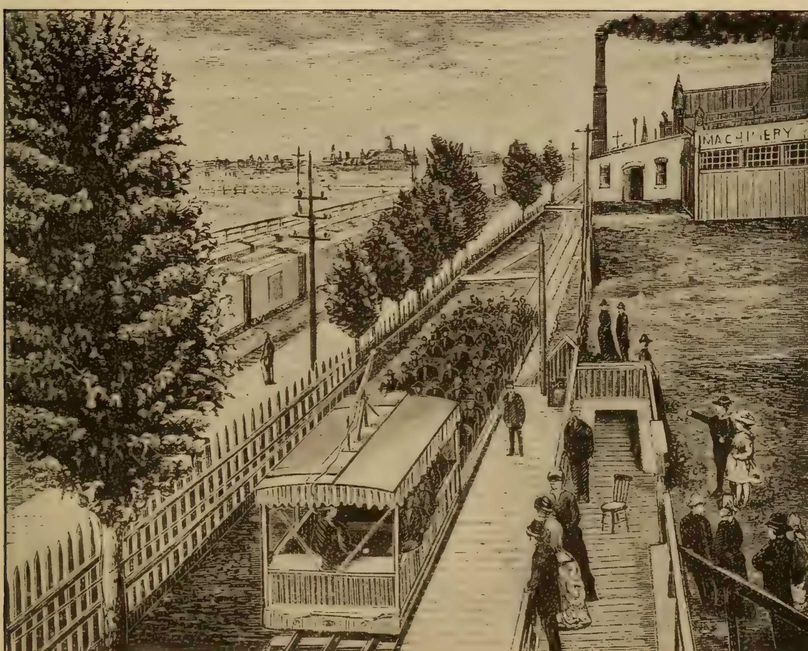
So much, without necessity to enter into further details, of the telegraph in Canada. In the attention given to electric power in other directions we are apt to forget the important place which the telegraph occupies, for truly the electric telegraph, to borrow the language of Samuel Smiles, binds the intelligence of continents together and

has practically put a girdle around the globe.

Canada has reason to feel a natural pride in the success of the telephone. Professor Alexander Graham Bell was for a number of years a resident of this country, his home being at what is known as Tutello Heights, near the city of Brantford, Ontario. There he made many of his experiments in multiple telegraphy, and also in telephony. The first line erected in Canada was from the residence of the inventor's father across his garden. Success having attended this initiative venture, a line of greater length was constructed, and from these small experimental beginnings has developed the telephone of to-day.

Hamilton can make claim to being the first place in Canada where the telephone was used for commercial purposes. This was in 1877. As is frequently the case, the element of competition played its part in the early history of the telephone and there were rival concerns at work, each anxious for the business that the future was sure to develop. Mr. Edison was in the field with his telephonic inventions, and the question has arisen to whom credit for the invention of the telephone should be given. I am not going to enter into this dispute here, but the following letter, under date of Oct. 13th, 1877, from Mr. Edison, throws a good deal of light on the question:

"Bell has done absolutely nothing new over Reiss, except to turn Reiss' from a contact breaking into an non-contact breaking telephone with permanent magnet, and worked the thing up to a success. The records of the patent office will show that myself (Edison), Bell and Gray started nearly together on acoustic telegraphy for Morse working, that Bell and myself dropped this for speaking acoustic, and that I dropped it first and was working on it before Bell. However, Bell got ahead of me by striking a principle of easy application, whereas I have been



THE FIRST ELECTRIC RAILWAY AT TORONTO, 1883.

THE POWER HOUSE OF THE TORONTO STREET RAILWAY CO.

plodding along on the correct principle, but harder of application."

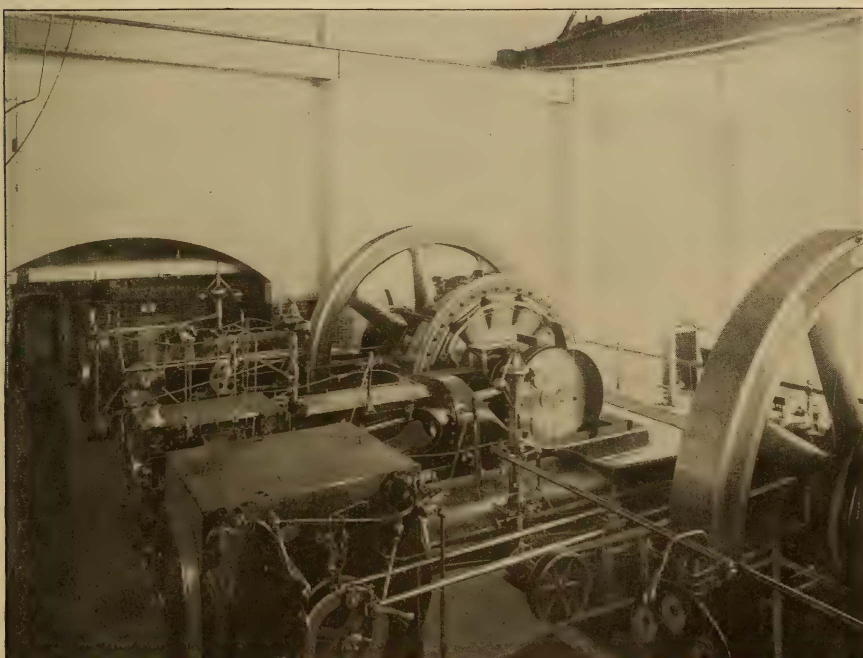
After a season of negotiations, telephone competition was finally settled, and the business is to day in the hands of The Bell Telephone Company. It was not easy for the public to appreciate the great convenience and benefits that were to come from the telephone, and the first canvass of those who endeavoured to introduce it into the leading cities met with little success.

All this is changed to-day. The telephone is known in the smallest hamlet in the Dominion and, relatively, as with the telegraph, the telephone is more generally used in Canada than in almost any other country. In long-distance work, whilst perhaps the same achievements have not been accomplished here as in the United States, it is not but what they might be. Canadian business men have been slower to take hold of long-distance telephony, and yet the long distance service of the Bell Telephone Company of Canada comprises 13,091 miles of wire on 5361 miles of poles, and provides the means of verbal communication between the subscribers to their 300 different exchanges, and also to 262 other places, where they have no exchanges but only toll offices.

The general statistics of the telephone show that on Dec. 31, 1894, there were 350 telephone exchanges in Canada

using the Bell instrument. These were represented by 32,485 subscribers, distributed as follows: Business places, 21,733; residences, 10,621; public pay stations, 131; and, in addition, 528 private line subscribers. For this service 34,595 miles of wire are in use over 300,000 poles, besides underground conduits and house-top fixtures. The headquarters of the Bell Telephone Company are in Montreal, Mr. C. F. Sise being president, Geo. W. Moss, vice-president, and C. P. Sclater, sec.-treas. The Ontario department has its headquarters in Hamilton, with Mr. Hugh C. Baker, manager.

Toronto leads in several important particulars in the use of the telephone. There are to-day in use in that city over 4500 telephones, distributed among houses and private residences. The Toronto system is nearly altogether worked by metallic circuits, and to a greater extent than is the case in any other city of the same size in America. The Toronto exchange is one of the most comfortably and perfectly appointed on the continent. Within the past year the largest installation board in the world has been placed in this exchange. The Toronto office is under the management of Mr. K. J. Dunstan, who has been identified with the telephone business almost from its inception. He is a gentleman who takes an active interest in electrical matters generally, and during the past year occupied the position ot president ot the Canadian Electrical Association.



INSIDE THE POWER HOUSE.

The one feature in the development of electrical power, that more than any other, makes it a present question with intelligent people of all classes, is the application of this subtle force to railroading, more particularly, perhaps, in street railway directions, and yet by no means stopping there. The first electric railroad operated in the Dominion of Canada is still a matter of conversation with the people, at least when its memories are brought before them once a year during the occasion of the hold-

A STANDARD, DOUBLE-TRUCK CAR OF THE TORONTO STREET RAILWAY CO.

ing of the annual Industrial Exposition, in Toronto, which brings its tens of thousands of visitors from all parts of the country. This road was constructed on the grounds of the Industrial Exhibition, and carried passengers from what was then the terminus of the street railway, then operated by animal power, directly into the centre of the Exhibition grounds.

This was in 1883, the road being put into operation by the W. A. Johnson Electric Company. Everything was of the crudest character, and no one, more than Mr. Johnson, is prepared to admit the immense contrast between that road of little more than ten years ago, and the splendidly equipped electric railways that are to-day in operation in all the leading cities of Canada. The electric generators were two six-arc light, 14-ampère Ball dynamos. The motor was a similar arc dynamo and was placed on an ordinary railroad flat car and connected with car axle by a belt. One rail took the place of the modern trolley wire and the other rail formed the return circuit. One little electric railway twelve years ago; thirty street and suburban railways in Canada in 1895, practically all operated by electric power, and none of them to compare in insignificance with the Toronto Exhibition railway of twelve years ago.

It is somewhat difficult to secure absolutely complete statistics of all the street and suburban railways in operation in Canada, but it came in the way of the writer within the past few months to gather statistics of this character that give a very perfect idea of the extent to which electric power is used for railway propulsion in the Dominion. In twelve railways, and not all the more important ones, fully $10,000,000 capital is invested. These cover 255 miles of road, and possess, as an equipment, 287 motors and 144 trailers. It seems safe to say that fully $20,000,000 capital is invested in electric railways in Canada.

This is not the place to enter into minute details, but it will be interesting to single out, perhaps, a road like the Toronto Street Railway, which, in several different ways, has proven a subject of comment among the people of the United States and other countries, and has served as an object lesson of the satisfactory manner in which a public franchise may be disposed of by a municipality for the profit of that municipality.

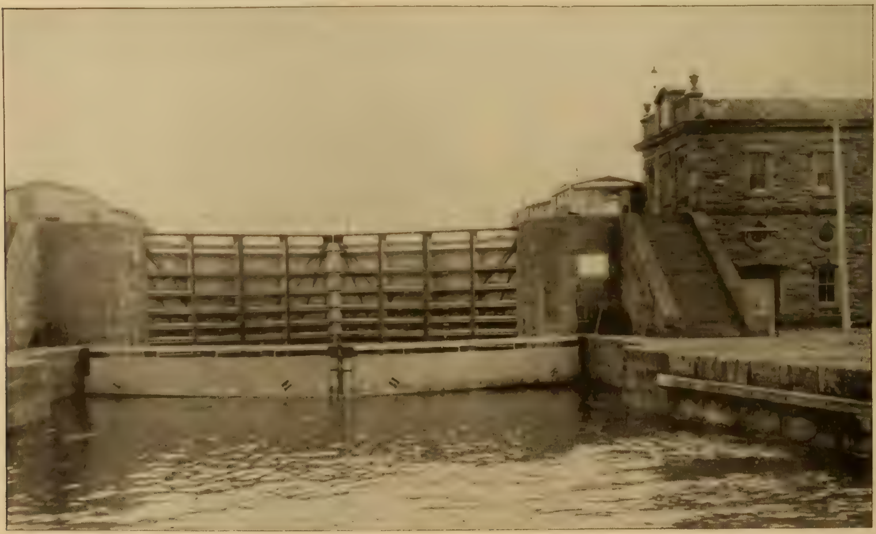
The capital stock of the Toronto Street Railway is $6,000,000. The president is Mr. Wm. McKenzie, and the superintendent, who has been identified with the street railways of Toronto almost since their inception in 1869, is Mr. James Gunn. The mileage is 81½. The systems in use are the General Electric, Westinghouse and Thomson-Houston. One hundred and sixty-six motors and seventy trailers are necessary to cover the business of the company. Few street railways anywhere possess better and handsomer railway carriages, the double truck cars and the parlor cars of the Toronto Street Railway being admired by the most expert railway managers who have had the privilege of inspecting them. The power house could hardly be open for much improvement. The plant comprises two 1600-H. P. engines, with multipolar generators, coupled direct, 800 K. W. each, working up to 2000 ampères each at 560 volts; four 620-H. P. and one 430 H. P. engines, with ten generators driven by belt, 200 K. W. each; output, 4000 ampères at

THE INTERIOR OF ONE OF THE CARS.

THE FIRST BOAT ENTERING THE LOCK OF THE NEW CANAL AT SAULT STE. MARIE, MICH., U. S. A.

560 volts; capacity of total output, 7000 ampères at 560 volts; indicated horse-power, 6110.

It is not necessary, however, to stop with Toronto in speaking of a well-equipped street railway. In Montreal, though the development there has been slower than in Toronto, the street railway service to-day is in splendid shape, a fact that is illustrated in the strong position that the stock of the Montreal Street Railway holds on the stock board.



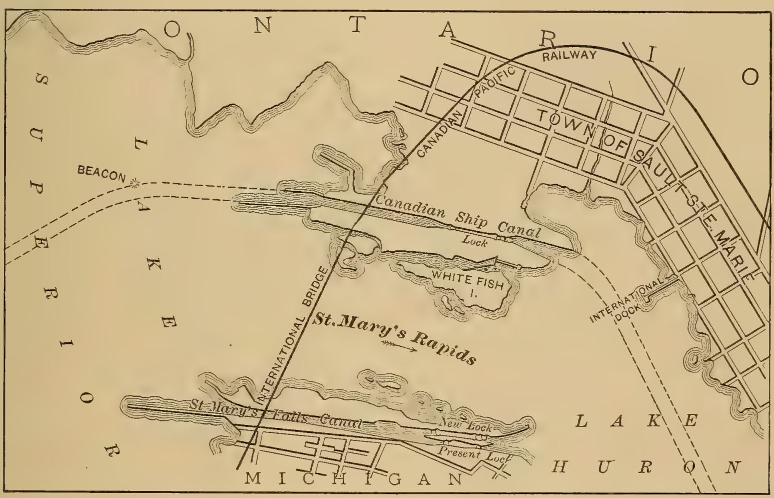
THE LOWER GATES AND POWER HOUSE.

In Ottawa, Hamilton, London, Winnipeg, St. John, N. B., Victoria and Vancouver, B. C., are also to be found well-planned and creditably equipped electric railways. These are more strictly street railways. When we come to the Niagara Falls, Park and River Railway, there is found an illustration of a successful road operated for the benefit of the travelling public. This road runs from Queenston on the Niagara River to Chippawa, a distance of about 15 miles, skirting the Niagara River. The fact that its promoters are to a large extent men like E. B. Osler, the president, who are prominent men in the Canadian Pacific Railway, is one reason, doubtless, that accounts for its excellent management, though the credit for this must, to a large extent, be given to Mr. Ross Mackenzie, the general manager, and an old railway man.

To some extent the experiment of carrying freight by the smaller electric railways has been tried with a good measure of success. The Galt, Preston and Hespeler Street Railway claims to be the pioneer Canadian road combining freight and passenger traffic. The average freight amounts to about 600 tons per month, and the number of passengers to about 20,000 per month. This road cultivates business with manufacturers by running sidings into all the factory yards in Preston and Hespeler, so that freight can be loaded at their own doors. The freight work is all done at night after 10 o'clock.

One does not need to be an optimist to express the view that, large as has been the development in electric railways in Canada, within what is really a period of five or six years, for data gathered show that it is easily within this time that many of the new roads have been opened and older roads have changed off from animal to electric power, yet electric railroading in that country is in its infancy. We see this in the fact that at the last session of the Ontario legislature no less than 12 electric railway companies were incorporated. It does not follow, in every case where a charter has been granted, that operations will commence at once, or possibly may not be entered upon at all, for the speculator is abroad in the field of electricity as well as on the stock board and in the wheat pit.

There is no doubt, however, that many new lines projected will go forward within a few years, and especially now as confidence is being restored in the financial world. In the western section of Ontario, in particular, and to



MAP SHOWING THE CANADIAN SHIP CANAL AND ALSO THE ST. MARY'S FALLS CANAL.

a comparative extent all throughout the province, it seems not unlikely that electric railway building will be followed in the lines of creating means of communication between towns and villages in the interior, and off from the regular lines of railways, and the front. This will serve a valuable purpose in opening out many sections of country.

When this day comes, the use of the horse on the farm, as is rapidly becoming the case with this animal in all our cities, and will become more certain if a success is made of the horseless carriage, is likely to become much restricted, for these short railways will carry the products of the farmer to the market towns, and no longer make it necessary that he should rise at daybreak and harness his team and start off on a journey of ten or fifteen miles.

Electricity is running the gas companies a sharp race in Canada, as well as in other countries. This applies more to the larger cities, where at one time gas had a complete monopoly. But the incandescent electric light has cut out for itself a field, that has been an invaluable boon to country towns, where nothing better than the coal oil lamp had been known. I refer to the extent to which incandescent lighting plants have been placed in the smaller municipalities throughout Canada. I asked the chief engineer of one of the incandescent lighting companies, who has probably supplied 75 per cent. of the lighting plants in operation throughout Canada, what these represented at the present time, and his answer was, 10,750 K. W. To a greater extent, probably, than in any other line of electric development, the use of electricity for the lighting of municipalities has grown to large proportions in Canada mainly within the past two or three years.

In Toronto, as in other of the larger cities, the field of electricity is divided between the incandescent lighting companies and the arc lights. The question of municipal control of city lighting has been before the people of Toronto and other places from time to time, but if one is to take the expression of opinion, as shown at the polls in Toronto not less than a year ago, when a by-law was submitted to provide the funds to erect a civic plant and was defeated by a vote of 8 to 1, the Canadian people have not yet reached the point where they are prepared to furnish those of socialistic views an object lesson in this direction.

The electric motor has become an important factor in manufacturing quarters in all the larger cities of Canada. It does not appear, however, that electric power for manufacturing purposes has cut into steam power to any serious extent. In conversation with the engineer of one of the larger companies recently, the view was expressed that the development in this direction was more in the placing of small motors in establishments, where steam power had not been used to any great extent, or was simply borrowed from some adjacent establishment. Manufacturers who have large steam equipments have not yet satisfied themselves, seemingly, that it would be a wise thing to cast aside their steam plants to make place for an electric plant. But even here signs are not wanting that this time will show itself in the comparatively near future.

Any sketch of the development of electric power in Canada, would be incomplete without a reference to the work of the Canadian Electrical Association, which was organized in the fall of 1891, and embraces in its membership the best men throughout the Dominion, engaged in the various departments of electric work. The annual meetings of this Association have always been fraught with greatest good and serve not only to keep alive interest in this question, but the papers have been of that high class that have done much to spread a knowledge of electricity, and point out to those engaged in the every-day practical working-out of electrical problems, means and ways of giving progress to this young but growing industry. The Association to-day numbers about 130 members, and the annual convention, which was held in Ottawa last September, was among the most successful held during the history of the organization.

A few years ago the Association appointed a special committee on statistics, who have reported from time to time, but so far they have not been able to secure that ready response from those from whom they have sought data, that would give real value to the statistics so far published. They have found, as newspaper men have frequently learned, that it needs very persistent effort to get anything like a fair proportion of people engaged in any particular work or business to furnish satisfactory information, if any at all, when asked to do so.

In the gathering of statistics, however, touching the electrical industry, the government statistician, Mr. Geo. Johnson, has been more successful. In a letter to the writer he kindly furnishes some valuable information, to be embodied in the new issue of the governmental statistical Year Book, of which he is editor. Mr. Johnson stated that the amount of capital invested in electric telegraphs and cables in Canada is $7,000,000 ; in electric railways the paid-up capital is rather more than $13,000,000 ; in electric light works, $4,113,771 ; in electrical appliances, $1,389,365, or in round figures about $27,000,000.

The growth of electrical appliances may be judged by the fact that in the census of 1881 there were found only two hands with electric works outside of those connected with telegraphy, while in 1891 there were 1190 hands, not including those connected with the electric cars. The employees, in 1894, connected with the electric cars numbered 2614 ; passengers carried, 57,000,000 ; miles run during 1894 by the electric railways, 15,500,000 ; miles of track for Canadian electric railways, 368, or 73 miles to each million of the people. The motor cars in Canada are calculated by Mr. Johnson as 658 ; trailers, 341 ; snowsweepers, 39 ; and motors, 891. The steam railways in Canada in 1894 carried 14,500,000 passengers, which, contrasted with 57,000.000 carried by the electrical railways, shows that four times as many passenger were carried by electricity as by steam, and that, on an average, every person in Canada had been carried 11 times in the year by electricity.

The opening of the new canal at Sault Ste. Marie furnishes an illustration of the operation of canal gates by electricity, that is claimed by the engineers to be the first attempt of the kind in the world. Electricity has got into the schools, and in the School of Practical Science at Toronto, in particular, it is one of the important branches of study. At the conventions of the Electrical Association the professors of this school have contributed generously of the information in their possession, which, partaking of the scholastic, has proven an interesting supplement to the practical, as given out generally by the members of the Association.

There is good reason to believe that in the developments which another decade will undoubtedly make in the electrical field, Canada will contribute no unimportant share.

ELECTRICITY IN 1895.

Retrospect and Prospect.

By Thomas Commerford Martin.

ONE of the freaks that engaged attention during 1895 was a poor lad who grew so fast he could not keep up with himself. By adding two or three inches every week to his stature, he rapidly overtopped notable giants of mature years; but just at the moment when he was expanding most visibly, his constitution proved unequal to the strain, and he gave up the ghost and quit. There were millions in him had he lived, but never before was it permitted to a humble human being to demonstrate so effectually in his own swift, physical career, the conditions and effects of a "boom"

He might well be regarded as a portent and a reminder to those who forget that solid growth is slow and that healthy permanence in the arts and industries or anything else must be won by steady and arduous stages of consistent endeavour and uplifting. Particularly in the electrical field would it be helpful to have on hand, for use at the enthusiastic feasts of new companies, exploiting new inventions destined to outrun anything the world ever saw before, the warning mummy which would prove that even with the best intentions it is possible to grow too fast and die too soon.

This may seem a hard saying after the dismal crash and dissolution of 1893, when, with peculiar violence and in exceptional numbers, the electrical concerns and industries of the United States went down in such painful collapse; but the fact is that the sharp lesson of punishment for over-expansion and undue booming was not fully learned. In truth, the genuine advances are so great all the time, and the promise made by electricity has so much of reality about it, that the trouble is to know what are the legitimate limits to the new work. It is not the electrical engineers who are to blame for high-wrought expectancy, but the public, which has got the notion into its head that if there is anything under the sun that electricity will not do, it cannot be worth doing. This feeling, of course, confounds the good with the bad, groups fraudulent fakes with great boons to mankind, and ranks openings for conservative investment with opportunities for wild-cat speculation. On the whole, however, it may be said, broadly, that aside from the inherent tendency of electrical industries to grow too quickly, and the desire of a few of them to get all their increase in a brief space of years, the evidence of 1895 has been that they exhibit a hopeful recovery from the results of turgescence and precocity, and a return to normal vigour and bulk.

First and foremost among the features of electrical advance in 1895, must be considered the new conditions established on the steam railroads, by an agency which some believe destined, in a few short years, to banish the steam locomotive from the face of the earth. Dr. Louis Duncan, of Johns Hopkins University, in his admirable inaugural address, as president, for 1895–6, of the American Institute of Electrical Engi-

T. C. Martin

THOMAS COMMERFORD MARTIN is a well-known writer on electrical subjects, and for a number of years past has been actively engaged in electric journalism as editor of one of the prominent periodicals.

neers, expressed his conviction that a crisis in the history of railroading had been reached, so far as concerns the motive power.

This opinion, extreme as it may seem to those who are not watching the tendencies of the time, is, undoubtedly, shared by large numbers of railroad engineers, electricians, and others interested in the problems of transportation. They could not very well resist it when, within the brief space of a couple of weeks they saw the excursion business of the Nantasket Beach branch of the New York, New Haven & Hartford R. R. in the United States handled successfully by electricity, and the equally effective application of a 95-ton electric locomotive to the hauling of heavy trains in the Baltimore & Ohio tunnel at Baltimore, Md. The range and flexibility of electrical methods could not easily be better illustrated, and the conclusions drawn from such work are emphasised by the general and rapid adoption of electricity for the elevated roads in Chicago.

It would, indeed, be difficult to name a leading steam railroad to-day that has not had the new problem forced upon it, while many are, themselves, actively engaged with the installation of initial equipments of electrical apparatus. Yet, true as this is, it would be unwise to infer that the change is to be instantaneous, involving the complete disappearance of the steam locomotive from the fields in which it has won such notable triumphs. On the contrary, the crisis marks the development of new conditions tending in two exactly different ways,—subdivision and concentration.

The "trolley parallel" that has ruined steam passenger traffic in some places, owes its success largely to the use of the small, frequent unit. The electric car, plying at a few minutes' interval, has left no fares for the heavy train, with a costly crew, running on an hourly schedule. It is obvious that the steam road can no longer hold its profitable local traffic if it adheres to the old method of train service ; but by the adoption of electricity it can send single or double cars incessantly over its lines and thus meet the competition, both as to frequency and as to low rates of fare. Anyone may observe this situation of affairs in the vicinity of New York City, where many popular resorts are now reached in trolley cars by swarms of passengers who, before, had to depend entirely on the steam lines. The same facts are not less striking in the vicinity of Philadelphia, despite the reduction of fares and the increase in the number of steam trains, the reason being that a trolley car can be caught at any moment at any point.

This necessity for a radical subdivision of local units is the present problem of many steam railroad managers, but it is traversed by the necessities attendant on through-passenger traffic and the hauling of freight. Thus, on the New York Central Railroad in 1892, the receipts for freight traffic were $26,000,000 (£5,200,000) or double those from passenger traffic, while the "local passenger traffic,"—a phrase of rather indefinite meaning,—was one hundred times heavier than the through-passenger traffic. These figures show that the freight business must have been handled,—as we all know it to be,—in long, heavy trains, and the through-passenger traffic to consist of a very small number of short heavy trains, both classes needing locomotives of such size that their development of from 1000 to 1200 H. P. is not at all unusual.

In this direction electricity has done nothing, nor is there any indication that it will do anything just at present. The big locomotives at Baltimore are for a special and peculiar class of work, on a very short stretch of track, with elaborate trolley devices, and with a plant likely to be in constant service. In France, tests are being made with a locomotive that literally comprises a central station on wheels, the main object being to get the higher fuel economy of the stationary engine in the generation of the current that is delivered to the motor on the driving wheels. But this complex arrangement is regarded very dubiously by many elec-

trical engineers, who believe that if electricity is to supplant steam on main stems, it must be by means of current delivered from power houses along the track, as in street railway work.

As a matter of fact, large quantities of freight are now being hauled electrically in the United States, more than a hundred street car lines in 1895 having made this a part of their work, but the service is comparable with expressage, and the quantities hauled are relatively insignificant. A large number of cross-country roads are also being built and organised, with the purpose of handling freight ; but this work is distinctly of a minor nature, the freight being, so far, in small bulk and subsidiary to passenger traffic.

Many inquiries also have been made, during the past year, from tropical regions, particularly the West Indies and South America, for electric roads of this character, to bring fruit, coffee, logwood and sugar down to the coast for shipment, the average load to be perhaps 40 or 50 tons, and to be supplemented by casual passenger business. Steam roads are altogether too cumbersome, it is found, for this work ; but light electric roads are evidently destined to succeed admirably in such a field.

But to return to the problem confronting the steam railroad manager, it will be seen that if his road is not a large one, the choice he has to make is perplexing. If he does not equip electrically, he cannot prevent a great deal of the local passenger traffic from slipping away ; yet he has no immediate use for electric methods of running his through and freight traffic ; and even if he wanted the innovation to be made, electricians are not ready to furnish either the system or the apparatus.

The conclusion that one reaches, therefore, on the results of 1895 is that many roads will not equip with electricity just yet, and will let the street railways absorb the bulk of their local traffic. Compensation must be sought in freight handling, and thus it is not impossible that one result of the introduction of electricity on street car lines may be to force many steam roads to advance their freight rates, as well as to offer new inducements for through travel. In reality, the abandonment of local traffic has begun, except in the case of the New York, New Haven and Hartford R. R., which, having lost pretty nearly all, has revenged itself by buying up the parallel trolley roads. Another contingency open to the relatively smaller roads is an alliance, or working partnership, with the trolleys, and the development of light freight roads in rural districts where much of the handling is done uneconomically by horses. In other words, the steam railroad must go to the freight, rather than wait for the freight to reach its depots from the back districts.

When we pass from roads with a couple of tracks to larger ones with from five or six tracks, the problem is, in one sense, greatly simplified for the manager, as it immediately becomes possible to equip profitably at least one set of tracks with electricity for the local traffic, in direct competition with the trolleys, and to use steam also at the highest economy and efficiency, on the other or the same tracks, for night through-traffic and for night freight. On this plan large steam roads can virtually absorb the trolley systems in the cities through which they run.

It has been pointed out that existing equipments permit motor cars to make a speed in cities of only 10 miles an hour, and, yet, to attain 40 miles out on the regular tracks between towns. In this way, a trolley car can pick up its passengers for a city 40 or 50 miles away while on its city rounds at regulation speed, and yet, when switched to the steam tracks, can let itself out at such a rate as to cover the whole distance easily in an hour. As a matter of fact, cars of this type are already in use on several lines.

If, on the one hand, the trolley car is not so replete with modern conveniences as the ordinary steam coach now is, on the other hand, a passenger, taken up casually at his own door and

delivered promptly at another door, 50 miles off, without any waiting or reference to time tables, is not apt to be exacting about details. If he be, the fact will not be overlooked that the electric lighting and electric heating of electric cars is far superior to the oil lamp and coal stove methods still prevalent on too many steam roads, and that most waiting rooms are as gloomy as portals of the tomb.

It may be remarked, that dealing with two forms of motive power will, in reality, not simplify, but complicate, the work of the railroad manager. But the objection is somewhat superficial. In nearly all large modern buildings, the combination gas and electrical fixture is in use, but it is not considered a disadvantage to have two methods of illumination at hand. Nearly all business offices to-day use the telephone and telegraph, but the benefits of the one do not interfere with those of the other. Each is used for the work to which it is best suited, and the best results are accordingly obtained. It is easy to believe that the command of two sources of motive power will be, to many managers, a distinct boon, and that their interdependence will afford many opportunities for work not now dreamed of. These seem, to the writer, at least, some of the electric traction developments and suggestions of 1895.

Before passing on to other branches of electrical work, it may be noted that trolley street car activity was well maintained during 1895, reaching a total capitalisation for the industry in the United States that cannot be placed short of $750,000,000 (£150,000,000), although the actual cash investment necessarily falls far below that. It is amazing that after a period of gigantic inflation the trolley properties have come so well out of the ordeal, and average up so well as to dividend earnings. Moreover, their periods of reconstruction promise to fall on better days, when they will have larger resources on hand.

The past year is remarkable for the diminution of the abuse against the trolley, and the display of a kindlier feeling toward it, as manifested in the expression of Charles Francis Adams last fall, when he characterised it as one of the foremost "humanising and civilising" influences of the age. Such praise comes rather late, however, for in several cities most encouraging progress has been made with systems by means of which the wires and contacts conveying current to the cars are placed under the surface of the street. The road put into operation in New York City in 1895, with a plow reaching down through a slot between the rails to the concealed conductors, is reported to have worked so well that virtually the whole city is to be equipped in a similar way.

Nor was this all, for both America and Europe saw a revival of storage battery traction, with many improvements, the most noteworthy being the location of the batteries on a tray between the trucks instead of inside the car body. Another feature of 1895 was the general demand for fenders and for lessened speed, with a widespread discovery of the truth that while out of a thousand fenders it is hard to pick a single good one, cars can be allowed to run at higher speeds than have been usual if they have good brakes, dependent upon air or other control, and not upon tired human muscle.

It is hardly necessary to tell the readers of CASSIER'S MAGAZINE, after its splendid issue devoted to Niagara, that electric power transmission was one of the distinctive features of 1895. Be the outcome of the enterprise at the Falls what it may, the fact remains that the work has been carried through, that by means of huge turbines and two-phase generators of 5000 H. P. each, current is being generated and delivered, that the plant is being enlarged, and that every effort is being strained to get the power into the city of Buffalo, 22 miles away, a distance several times less, for instance, than that of at least two of the transmissions which have been steadily successful for a year or two past in Southern California.

Meantime, such is the immediate demand for the current right on the spot

where it is reclaimed from the hitherto wasted water powers, that it would seem as though the longer deliveries could wait a bit without much harm being done to anybody. The eyes of the world have been fixed on Niagara, and several new utilisation schemes, of lesser magnitude, have been set on foot. In fact, it is to be feared that many of the promoters and their friends will be disappointed, chiefly because they forget four things. The first is, that water powers are often costly to develop; the second is, that streams have an exasperating knack of drying up, and during 1895 the U. S. Government actually forbade the power use of some of them; the third is, that the power from coal, natural gas and oil is still wonderfully cheap; and the fourth and main consideration is, that even when you have developed your power cheaply, there is not always a market for it.

But 1895 undoubtedly saw some valuable work done in "electrifying" water powers, and a stimulus given to kindred work. For example, at Wilkesbarre, in the American anthracite regions, Mr. J. H. Vail, in designing a new central station, planted it right in the middle of the culm piles that are to serve as its fuel, and actually had to dig its foundations out of what was a veritable coal mine on top of the ground.

Incidental to power transmission, is always the question of distribution, and it is noteworthy that 1895 saw the use of electricity on the Erie Canal, close to Niagara, by means of "electric mules," or motors hauling boats along, from stout lines on poles, thus abandoning the cruder method of using the trolley system and attaching the motor to a propeller which churns up the water and chews up the bank. The writer believes that the equipment of the whole Erie Canal will swiftly follow, section by section. Under "distribution" also may be included the work being done in the equipment of mills, factories and machine shops with electric power, the motors displacing all other agencies and being run from a central power house. A long list could be given of the establishments thus fitted up during the last twelve months.

Another form of the use of electric current in large bulk, during 1895, has been its application to the arts of metallurgy and chemistry. Aside from the work in aluminium and carborundum at Niagara Falls,—which was already familiar on a smaller scale,—we see the production of calcium carbide in large quantities by means of electric current turned loose on a mixture of lime and coke. When water is brought into contact with the calcium carbide, we get the new acetylene gas which has such a brilliant flame and such an abominable odour, and with which, it is said, the whole business of gas making is to be revolutionised. This material is reported also to open up, for easy production, a long range of other good things in chemistry, and steps were taken last year to manufacture it in large quantities.

In electro-metallurgy, further interesting developments were seen in the art of welding, and Mr. G. D. Burton came forward with a very plausible story about the reduction by electricity of precious ores combined with a liquid solution, so that the metals in the ore separate and run according to the different degrees of heat required, the metals being found at the bottom of the tank in shot globules.

From this newer ground, where so much remains to be proved, let us get back to older territory where the facts are more commonplace, though the territory for occupation is equally illimitable. Electric lighting during 1895 cannot be said to have presented any very startling innovations, though various inventors, notably Nikola Tesla, Dr. M. Pupin and Mr. D. McF. Moore, brought to notice plans and devices for giving us commercial vacuum lighting, i. e. plain bulbs in which, by means of electric agitation, the ether is made to glow and furnish illumination, either with or without the aid of the accustomed filament.

Who is bold enough to say that the goal is not well within sight? Knowing

how wasteful the best of the old methods are, and how readily the ether glow can now be obtained, it is natural that inventors should devote themselves attentively to such a fascinating problem, whose solution would bring immortality, to say nothing of wealth. Yet it is curious to comment thus on these advanced ideas and then to turn to the bold assertion of Mr. S. D. Greene, that from 1880 to 1895, not a single step ahead had been made from the fundamental principles laid down by Edison for electric lighting in cities ! If that be broadly true, it would, in itself, be an argument for the desirability and timeliness of another big stride forward.

One of the striking aspects of electric lighting in the past year was the large increase in the number of municipal plants and of plans to spend public money on such work. It is not quite certain whether this is a lasting element in the industry or one of the signs of bad times, when the taxpayers clutch at any hope of reducing expenditures. There are some well-managed city plants, but in spite of the many investigations made, the writer is ready to assert that not a scrap of evidence has yet been brought forward proving that, on the whole, a city saves money by going into debt in order to engage in a commercial undertaking of this kind. It is worthy of note that, offsetting the desire to increase municipal debt in this way, a contrary tendency has, of late, shown itself to put existing private plants under State control and to protect them in their investment, against undue competition, while they give good and cheap service.

Speaking technically, the main changes in the electric lighting field in 1895 have been the greater use of direct-connected incandescent dynamos ; the general introduction of larger arc dynamos up to 150 lights of 2000 candle-power each ; the growing employment of 220-volt incandescent lamps ; the resort to storage batteries in central stations and isolated plants ; and the increased favour shown towards inverted arcs whose light is thrown up to the ceiling and reflected downwards. Of the old red-hot controversy between the direct and the alternating current little was heard ; it is the battle of the "phases" that is now on."

In telegraphy, the course of years has brought about singular changes. It is now the smallest of the four great branches of applied electricity, though the oldest. That telephony should have surpassed it in magnitude and usefulness, may have been inevitable, but there are those who regard the relatively inert and unprogressive state of telegraphy as largely due to those who are its business managers. In the United States the telegraph barely paid its way during 1895, but in England, the loss for the past seven years reaches $13,000,000 (£2,600,000), and the end of deficit is not yet. The competition between telegraph and telephone is something like that betwen steam road and trolley, with the chances favouring the younger, cheaper and more flexible system.

It has recently been suggested by Mr. P. B. Delany, that, by the use of machine methods, the telegraph can not only hold its own, but cut deeply into the mail service now done by "special delivery," and he has illustrated his ideas by sending about as much as three pages of this magazine in one minute. Letters fired over the wire in this way, between New York and Chicago at, say, 15 cents (7½d.) for 75 words would remodel social and business intercourse and compete with the mail as well as with telephone talks at four or five dollars (16 to 20 shs.) for five minutes.

Telephony has, however, taken a tremendous hold upon the present generation, which last year, in the United States, sent not far short of 10 telephone messages per individual. The long-distance lines ramify throughout the country, exchange service is rapidly increasing, and new ways of applying the instrument to public needs are hit upon daily, such, for instance, as putting a special telephone in your house when anybody is ill there. The past year saw, also, a swift and sudden de-

velopment of competition with the company that has monopolised the field these twelve or fourteen years.

The expiry of some patents, the uncertainty about others, and the general yearning for cheaper telephony, has called a number of new concerns into existence, good, bad and indifferent, which are putting in exchanges and private lines right and left. It is difficult to believe that in large cities more than one telephonic network of intercommunication can logically and profitably exist; but with that limitation, the era of telephonic development can be said to have only fairly begun in 1895. Whether it is to end in the complete supercession of every call bell, hotel annunciator, and speaking tube, time must demonstrate.

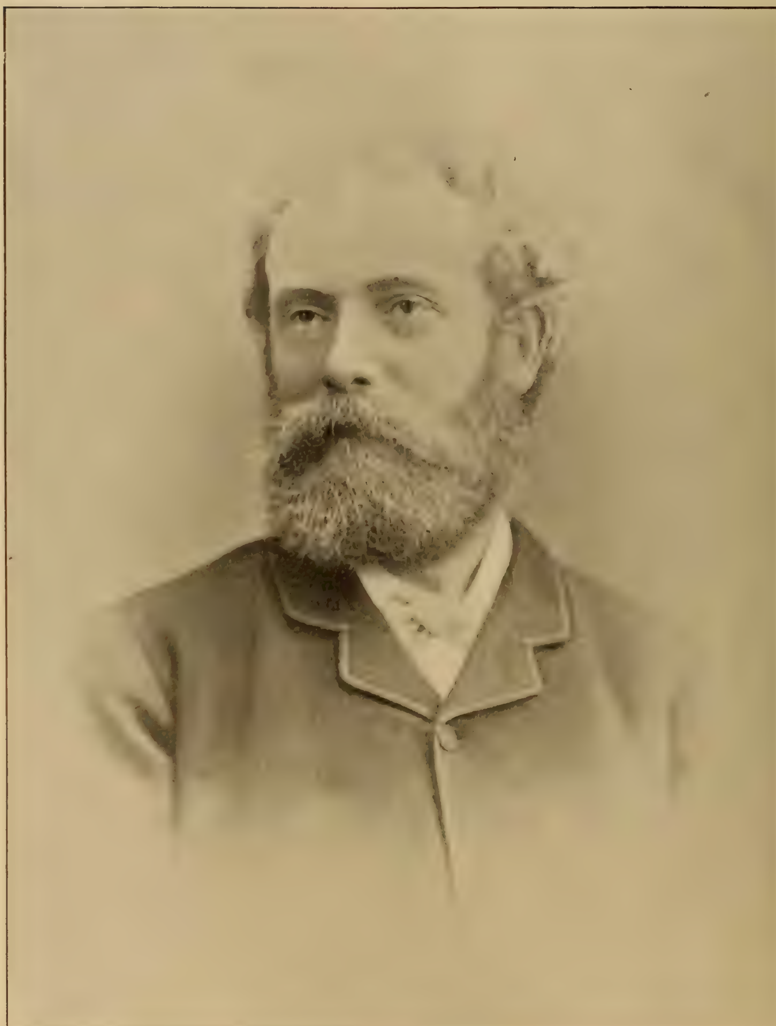
The application of electricity to navigation has already been touched upon in reference to the Erie Canal, but, beyond that, a good deal of work was done in the equipment of single electric launches and small fleets, the latter being operated by trolley roads, which charge the batteries from their pole-line circuits. In Philadelphia the police force has been provided with one of these boats as a means of silently patrolling the river front. In Philadelphia, too, the city has taken up the latest ideas in sanitation by fitting up an electrozone department for itself. Electrozone, or salt water through which an electric current has been passed, is now accepted as an excellent disinfectant or purifier, and the cleanliness of the Quaker City is to be enhanced by its use.

Back of all the utilisation of electricity lie hopes of getting current more cheaply, and work goes on in two directions,—greater economy in the use of steam or fuel and the turning of heat directly into electricity. During 1895, Mr. H. B. Cox brought forward some noteworthy improvements in the thermopile with which, put over a stove or a gas flame, he now can obtain current in considerable volume for long periods. His results have been watched with much interest.

On the other hand, Mr. Tesla has brought forward his oscillator, practically perfected, in which, by combining the steam engine and the dynamo into what is essentially one mechanism, operating under conditions of highest regularity and efficiency, he has cut down the consumption of steam at least one-half, for the same quantity of current, and has also secured that current in a form which renders it remarkably useful to work with. Mr. Tesla had wished to place on the market during 1895 these machines from which so much is expected; but the fire which destroyed his laboratory has involved a long delay. He is again hard at work, and a man who never hurries and never stops must be allowed to reach the goal in the way best suited to his temperament and judgment, regardless of a public that is ready to interpret, in the case of all inventors, every hope as a definite promise, and that insists on the immediate fulfilment of plans requiring the devotion of a long lifetime.

And this last comment is true of electricity itself. It may seem that the hasty sketch just given of a year's work and thought covers no small amount of achievement, but those within the circle realise that the net result is slender and light compared with the expectations and the possibilities. To workers in other fields it must often appear that the electrician is wont to be arrogant and aggressive, not recognising the fact that there is no such thing as universal dominion.

But, after all, what shall the electrician do, except follow the onward, widening path of his science and art? Modestly but determinedly, he must perform his duty in trying the subtle agency with which he is entrusted to the full extent of its powers and of his own.



John I. Thornycroft

CASSIER'S MAGAZINE.

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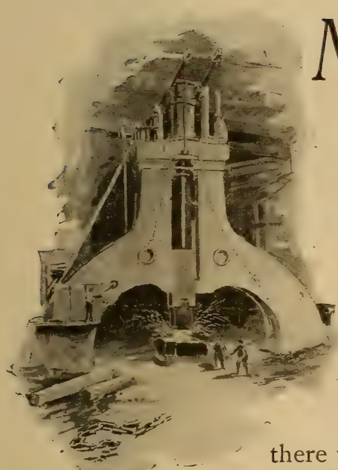
MODERN SHIPBUILDING TOOLS.

By J. Arthur Gray.



MACHINE-TOOLS for shipyard use, are a specialty of which the manufacture forms an industry of no mean proportions. Tools of this class have risen in importance with the growth and progress of iron shipbuilding. Only a short time ago there were no such tools in existence. There was no need for them. There are men still living who can remember when the shipyards of his early days were furnished with appliances very different from those which form the subject of this article, for ships were not then built of iron. Oak was the chief material of which our floating fortresses were constructed. The maritime traffic of the world was conducted in vessels of timber. And though many machine-tools are now in use for the working of the wood still required for the interior fittings of ships, wood-working machines will not be included in this description.

When the first attempts were made to build hulls of iron, there were very few tools of a suitable kind available. To start this kind of work was to start a new handicraft, and the men who were put to the work hardly knew themselves what they wanted, or what was likely to serve the turn. Some experience of the work was necessary to reveal the needs of the workmen, and how to furnish them with suitable appliances. The steam boilers of the time were the only structures whose manufacture demanded tools for clipping wrought-iron plates, and for punching holes in them. Boilers had been made of iron since 1786,—nearly 50 years before iron was used for the building of ships. The haystack boiler and the flat-sided return-flue boiler, had been constructed for the low pressures which were then deemed sufficient. And there were a few tools in existence that served, after a fashion, to punch and shear iron, and even to bend the iron plates, which, at that time, seldom exceeded ⅜-inch in thickness. If a young mechanic of the present day could see one of those primitive punching tools, he would hardly recognize in it any resemblance to the ponderous structures that are now to be seen in shipbuilding yards.

The punching machine of the early period consisted simply of a lever, the long arm of which was raised by a cam at a slow speed, and allowed to descend

A MAN OF WAR IN ITS EARLY STAGES.

by its own weight. The short end was provided with a steel punch and, of course, a die was fitted underneath. This "bear," as it was called, was sometimes made of duplex form,—another lever, working at the reverse end, did the shearing. And it is curious to observe that though the form is now altogether dissimilar, the principle on which these machines were designed, is still maintained in the best machines of the present day.

At that period the bending rolls seldom exceeded 12 inches diameter, and were short in length, for the plates to be bent were narrow. One roller was placed directly above another, and both were driven by gear. When a plate was passed between these, it encountered another roller which ran loose in its bearings at a higher level; and thus the plate received a curve as it glided on its way. If the bending imparted was not sufficient, the roller was raised a little higher by hand screws, until the required curvature was obtained. Those primitive tools, designed for boiler-making, were naturally the only tools that could, at first, be brought into requisition for the building of an iron ship.

The frames and shell-plates of canal boats were of light scantling, and were not troublesome to deal with. Angle irons naturally formed the keel and flange for attachment to the first strake of plates in the small craft first built; but when larger vessels were required, the plates were flanged along one edge and thereby riveted to a keel bar. Those keel plates which formed the garboard strake, were heated to redness in a furnace and were then taken out and the flange formed, with more or less approximation to the angle required. That flanging was done by hand hammers, over the edge of a block of cast iron.

The workmen that were first set to build hulls of iron, were not ship carpenters. They were quite unfitted, by training as well as by natural antogonism, to such work. They looked with jealous eyes on the innovation that threatened the ruin of their time-honored handicraft, and their fears were not without reason. Blacksmiths and boilermakers were the artisans employed, for their skill was most analogous to what was required in this new industry. Shipwrights modelled the hull, and shipwrights were still necessary for executing the woodwork of the ship, as well as all arrangements for launching.

There are many eminent shipbuilders now living who commenced their career as constructors of wooden ships. But the days of timber, in Europe at all events, are ended, and only in a few parts of the world is wood still employed as a material for large vessels. Wood shipyards in Great Britain, the home of iron shipbuilding, have been gradually transformed, and the materials of construction, as well as the tools used on those materials, have become wholly changed in character. The sound of the saw and adze, and the fresh smell of new cut oak, are no longer the characteristics of the shipbuilding yard. They have been replaced by the sharp bang of the punch, the metallic rattle of iron wheel gear, and the merry tapping of the riveters' hammers.

To trace the progress of ship-yard machine-tools of all kinds is simply to illustrate the universal law of evolution. The tools have developed newer forms and increased their powers in degree commensurate with what has been required of them. And so rapid, some thirty-five years ago, was the growth of iron shipbuilding, that the demand for suitable tools seemed to be far in advance of the power of supply. In fact, another new specialty, that of shipyard tools, had to be organized, and a new field was quite freshly opened

THE UNITED STATES TRIPLE SCREW CRUISER "COLUMBIA" IN THE DRY DOCK.

up for inventive talent. Sometimes the tool-makers, and more frequently the intelligent tool users, saw what was most likely to serve the needs of the time. The skill of the one, united to the aims of the other, helped to evolve the kind of tools required.

At first, these were much too light. Larger and stronger appliances were hardly set to work when it was found they were unequal to the duties imposed upon them. Frequent were the breakdowns of the machines that had been constructed too slenderly to meet the expanding needs. The shipbuilders demanded stronger tools of larger capacity; and few toolmakers had the foresight or enterprise to grasp the requirements as they arose. Iron ships were ordered of increased size; heavier plates and angle bars became necessary; the iron works had to increase the size of the puddled blooms, and to enlarge and strengthen their rolling plant, and the thicker and broader plates had to be bent and punched by machines of heavier calibre.

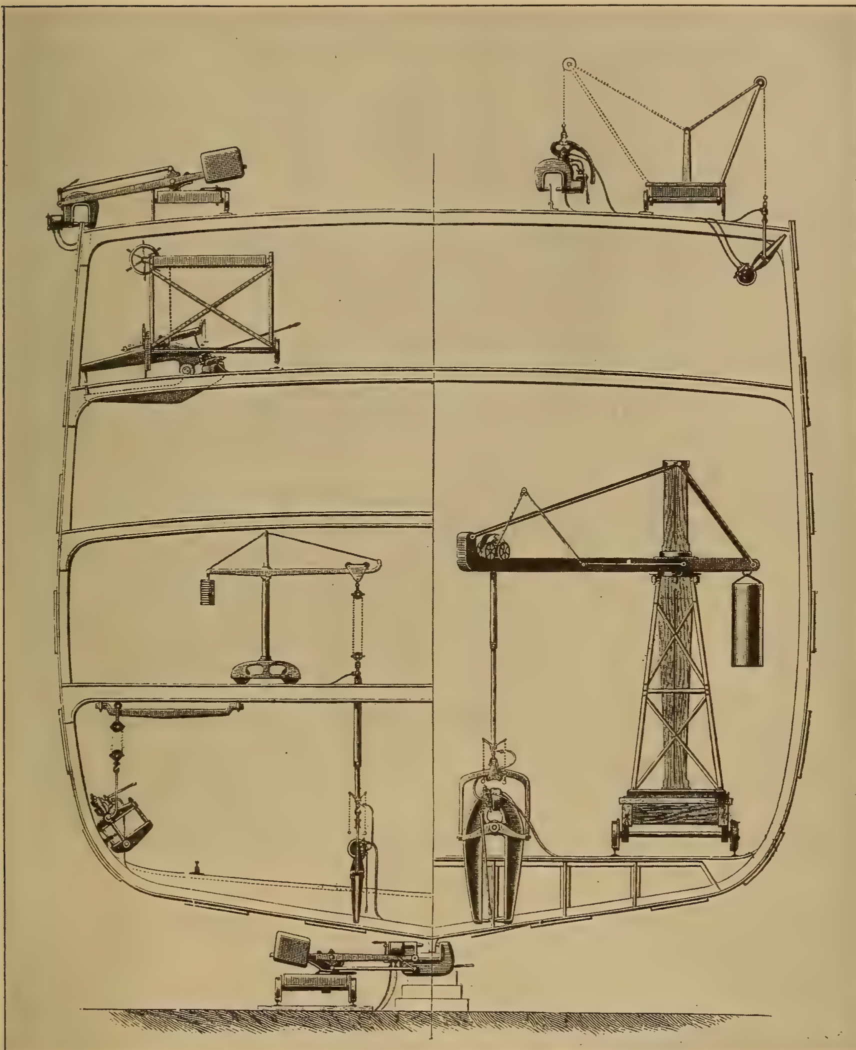
This rapidity of growth was not met by a corresponding rapidity of production in tools. For a long time iron manufacturers could not roll ¾-inch plates longer than 10 feet or wider than 3 feet. Those few enterprising makers who increased their plant to cope with larger plates were enabled to charge extra prices when plates of a given thickness exceeded a given superficial area. These extras checked in some degree, the aspirations of the marine architect who wished to use larger and wider plates, and the same cause operated to limit the need for larger machine tools.

A punching machine with a gap or gullet of 18 inches depth was sufficient to punch into the centre of a plate 3 feet wide. A plate bending machine that was 10 feet wide between the housings was quite equal to rolling the limited sizes of plates that could be procured at the minimum prices. But soon the shipbuilders saw that the saving of joints, butt-straps and riveting that could be effected by using larger plates was sufficient to cover, in many cases, the increased cost of such plates, not to speak of the superiority of the hull in lightness and strength. Then some improvements in the manufacture of steel of mild quality led to its being put forward as the material for shipbuilding; and when steel manufacturers put down rolling plant of such enlarged dimensions as enabled them to produce larger and heavier plates of that material at as low a price relatively as smaller and lighter ones, then all extra charges for increased sizes of plates were abolished. Shipbuilders were free to order plates of any length and breadth, and new shipyard machine-tools had to be constructed of enormous size and power to fit them for grappling with these unusually large and heavy scantlings.

Some yards were completely metamorphosed. The smaller and now useless machines, often in a decrepit or debilitated condition, had to be removed and replaced by larger appliances with a more vigorous constitution. And now a modern shipyard that is properly equipped for executing work quickly and cheaply, requires to be furnished with such powerful and enormous tools of various kinds, that the laying down of an establishment of this kind can be entertained only by large capitalists or companies.

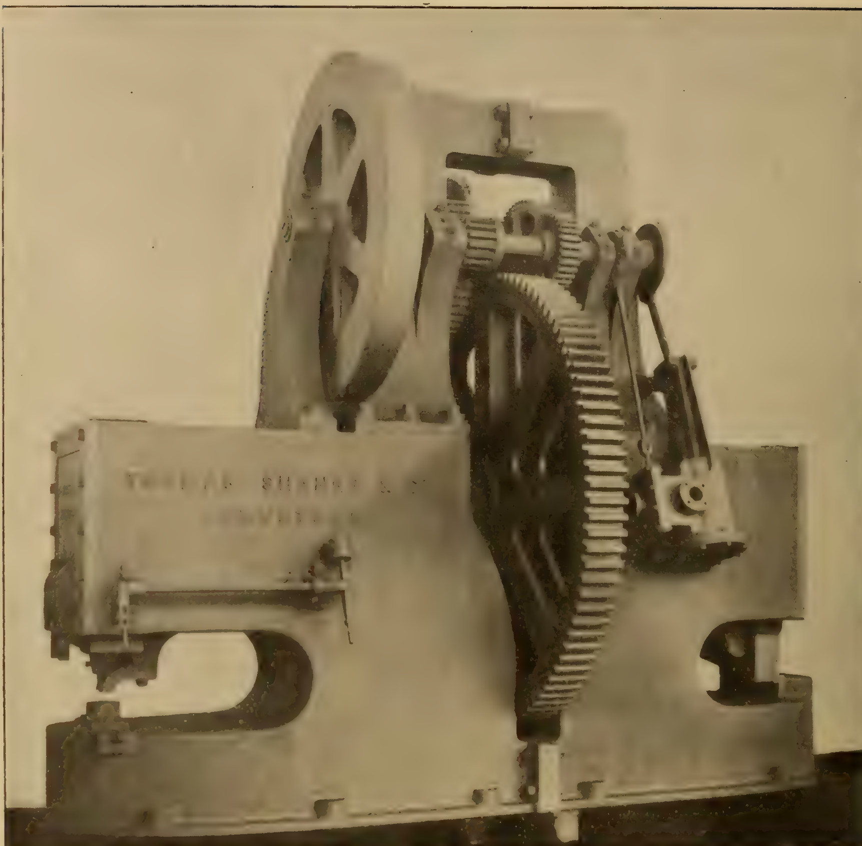
It will readily be inferred that during this period of activity and growth considerable fortunes were made not only by the builders of ships, but by iron and steel manufacturers as well. A few toolmakers profited largely by the urgent demands made upon them. But these lively times have passed away, and who can tell whether any similar boom may ever occur again? There is reason to believe that if any toolmaker should become rich now, it will not be by the largeness of the demand, but only by his enterprise in anticipating wants, or by the ingenuity whereby he may devise labour-saving appliances to cheapen as well as to improve production.

It will be interesting to note the changes in form as well as enlargement in capacity, which machine-tools in a



RIVETING MACHINES ON SHIPS' FRAMEWORK.

shipyard have undergone. No machine tool has ever been required in the bending of the angle irons which generally form the ribs or "frames" of the ship. With the exception of a few in the middle, there are hardly any two frames which are identical in curvature. They must nccessarily alter their form as they procced from the middle towards the stem or stern of the ship. These frames are therefore heated in a long turnace till they are almost white hot. Then they are easily bent round a row of iron pins, which are set up in the cast-iron floor, to lines drawn by scrieve boards for each individual frame. When thus bent and hammered down on the level plates they are left a short time until they are black cold, and can retain the shape given to them. With the exception of bevelling, referred to further on, all the



LARGE PUNCHING AND SHEARING MACHINE, DOUBLE PURCHASE, FOR TWO-INCH STEEL PLATES, FORTY-THREE INCH GAP; WEIGHT, FIFTY TONS. MADE BY THOMAS SHANKS & CO., JOHNSTONE, SCOTLAND.

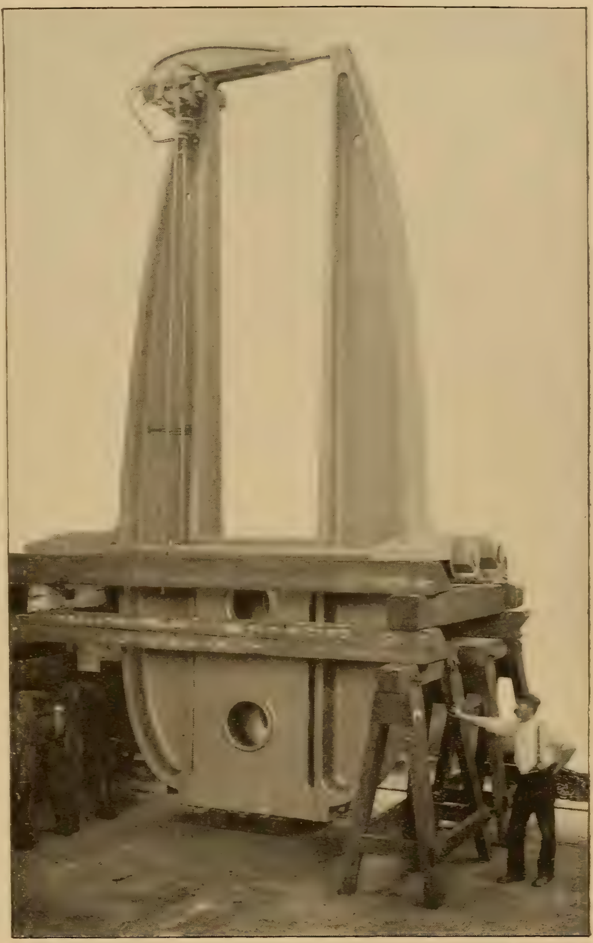
machining these require is cutting off by angle shears to the proper lengths at the ends, and punching the rivet holes, the latter operation being most conveniently done by a horizontal punch.

It is in the plating of the ship that machine-tools become necessary. The first strakes of plates, which are applied next the keel bar, have to be flanged along one edge. These, in early times, were heated and hammered as already described. But this hammering made very imperfect work. The plate could hardly be made smooth, and the marks of the hammer were too apparent. So a rude form of machine was brought into use to do the flanging. It consisted of a large oblong block of cast iron, somewhat longer and broader than the plate to be flanged, and over the edge of this a roller was made to pass. This roller was carried by two levers of the second order, one at each end of the block, and these levers carried the roller in suitable gudgeons, which could be wedged higher or lower on the beam as might be necessary. When the heated plates were laid on the block and secured thereto by clamps, the roller was brought down by the levers, and the purchase was augmented by pulley blocks and tackle. Of course, one lever could be depressed more than the other, and thereby give a twist or skew to the plate to mould it in conformity with the lines of the ship. This rude appliance, though it needed many men to operate it, made very

good work as compared with hammering.

When the bending roller was stiff enough, it gave the plate a smooth, even set, greatly superior to the irregular plate that resulted from hand hammering. Then an improvement was effected by using wheel gear of double or triple purchase instead of the pulley blocks and tackle. The levers were replaced by a spur quadrant at each end. The plate was held fast by an upper beam, balanced by counterweights so as to be readily raised or pressed down to grip the plate, and in this form the keel-plate bending machine was in use in nearly every yard, and did excellent work for many years. Its principal fault was its liability to break down. The cast iron blocks, which held the plate, became hot, and as this heating was communicated partially,—the surface in contact with the hot plate receiving most heat,—the main casting frequently cracked, or broke transversely. There was little use in increasing the thickness or strength of the parts. Thick beams of cast iron, made hot on one side only, were quite as liable to fracture by unequal expansion as thin ones.

Some makers got over the difficulty by making the blocks of box form to contain water; and so long as the parts were kept filled with water, the temperature could never rise high enough to cause fracture. But unless some self-acting arrangement was provided to maintain a head of water, the loss by evaporation left the lower beam as liable to crack as before, and in nearly every yard broken machines could be seen, patched with wrought-iron plate. Held together in this way, they served, perhaps, better than before. At all events, they were not so liable to break a second time, for the fracture afforded relief to their expansion and contraction. So long as the garboard strakes were bent hot, this machine answered well, but when steel plates superseded iron, a change in treatment became obligatory. No one ever dreamt of flanging the malleable iron plates cold. To have done so would have too severely tried



A SIXTEEN AND A HALF FOOT GAP HYDRAULIC RIVETER, BUILT BY MESSRS. WM. SELLERS & CO., PHILADELPHIA, PA., U. S. A.

that material as then used in shipbuilding.

It is hardly necessary to say that the iron plates used for the shells of ships were of the very commonest quality. And the builders could hardly be blamed for buying the cheapest. But even a good quality of wrought-iron plate, such as was used for boilers, would hardly have stood the ordeal of being bent sharply over to a right angle, without showing a fracture or tendency thereto. The introduction of steel plates changed all that. It was soon found that steel plates could be got of so mild a quality as to bear cold bending with perfect safety,—nay, that cold bending, if it could be done, was preferable to the hot bending of steel.

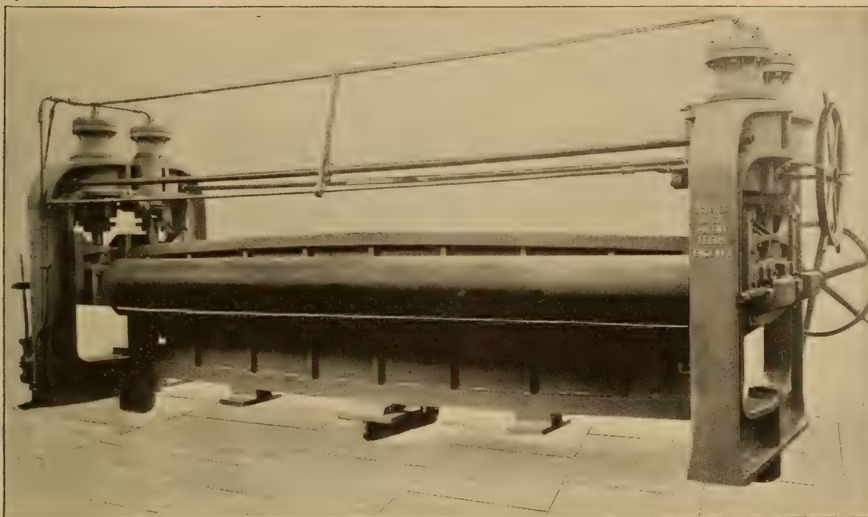
All engineers will remember the controversies that arose as to the effect, detrimental or otherwise, of heating steel plates. The outcome of that controversy was a general agreement among users, that if a steel plate must be heated at all, in order to do any flanging that might be necessary, then it became absolutely essential that the plate, after its form was completed, should be carefully annealed before being riveted into any structure of which it was to form a part. Marine boiler makers have been much exercised on the subject. It has been the theme of many a discussion in technical societies.

Now there is a general agreement in the opinion that steel plates, whether for boilers or for ships' plating, should be worked cold. If it only made better or more reliable work, we might have expected to see the shipbuilders set their face against the innovation, but the cold bending process was found to save a great deal of cost in time and fuel, and that consideration weighed more powerfully. Above all, it is clear that if a steel plate will not bear cold flanging to a right angle without showing sign of failure, then it is not fit for use and ought to be rejected. But the flanging of thick steel plates implies the use of some very powerful machinery.

We all know how hydraulic power has in recent years been brought into requisition for machine tools of all kinds, and how it continues to grow in favour; how it has been applied to machines for punching large manholes out of thick boiler plates, for flanging, and for riveting and bringing closer together the thick plates at the joints; and the noiseless and effective manner in which the work is performed. Given, the demand for a special machine, and the maker soon appears. Shipbuilders asked if they could get a machine that would flange their thick keel plates, say, up to thirty feet in length without heating them. The power required to do so is enormous, but, by the aid of hydraulic cylinders, the operation has been found quite practicable. There are now several makers of such machines in Glasgow and Leeds.

The principal difficulty, at first, was the holding fast of the plate with an unyielding grip, while the bending roller, actuated by hydraulic rams, did its work. No system of jamming by powerful screws was found sufficient. One firm, in Glasgow, patented a scheme of holding by making the machine like a gigantic vise, of cast iron with fixed jaws, and by fitting into those jaws long tapered wedges which were pushed up and drawn back by small hydraulic cylinders. But this, though effective, is rather a clumsy expedient. Another maker in the same city simply adapted the old design of lever quadrants, moved by hydraulic cylinders to raise or lower the roller, and used separate cylinders for the holding-down beam.

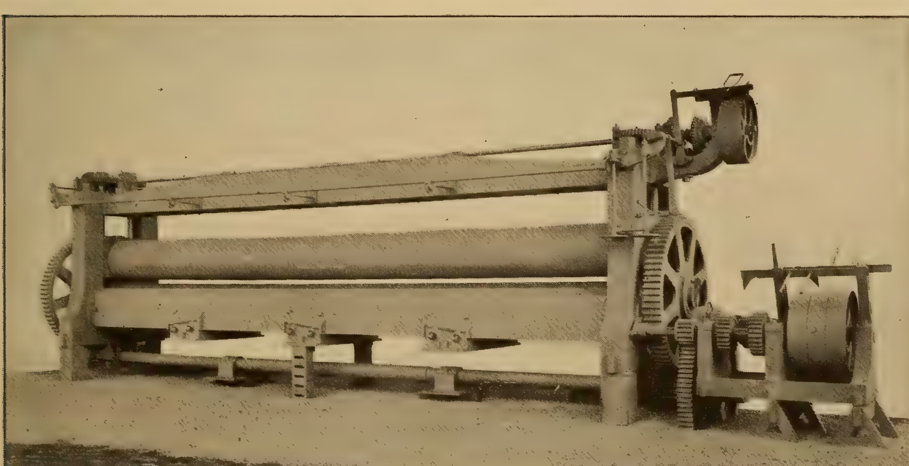
It is unnecessary to attempt a verbal description further than to say that these machines require to be of immense strength and rigidity. Some are over 100 tons in weight. They have been constructed to flange a cold steel plate up to thirty feet in length and one inch in thickness; and this they have done with as much apparent ease as if the plate was a thin sheet of lead. The problem of flanging a cold steel plate of such dimensions has been satisfactorily solved; and although only a few of the larger establishments have seen their way, as yet, to the acquisition of such costly plant, there is no doubt that the



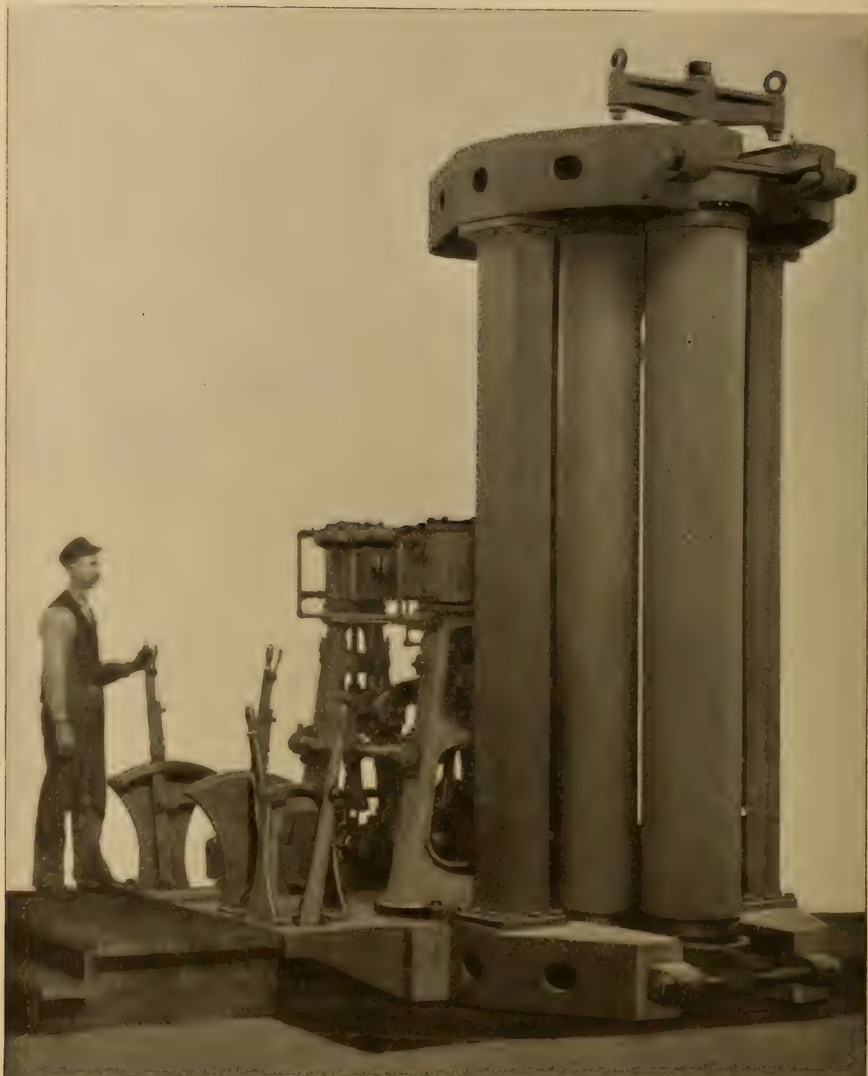
HYDRAULIC KEEL PLATE BENDING MACHINE, BUILT BY MESSRS. SCRIVEN & CO , LEEDS, ENGLAND.

excellence of the work obtained, and the economy resulting, will render the use of such machines imperative in every shipyard.

But what is to be said about bending rollers? If plates, 30 feet in length, are to be used as the garboard strakes, they ought to be used of the same length throughout the upper strakes of the hull. These other plates do not require flanging, unless, indeed, a system of building a hull by plates alone with internal flanges should some day be adopted. But the plates have all to undergo cold rolling, not only to take out the "kinks," but also to straighten or even bend them slightly, and that curving can be imparted to the plates only when they are put into the rollers broadside on. Therefore the rollers must be quite as long at least as the plates.



A SET OF PLATE BENDING ROLLS, SOLID FORGED STEEL TOP ROLLER, THIRTY-ONE INCHES IN DIAMETER; WEIGHT FORTY-TWO TONS. BUILT BY MESSRS. THOMAS SHANKS & CO., JOHNSTONE, SCOTLAND.



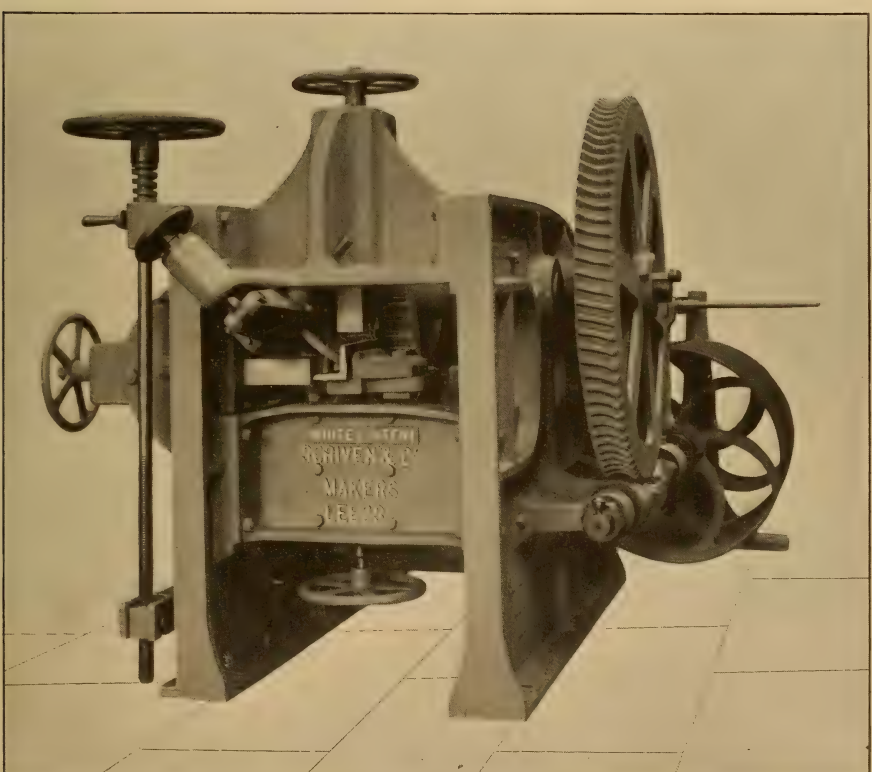
VERTICAL BENDING ROLLS, BUILT BY THE NILES TOOL WORKS, HAMILTON, O., U. S. A.

No such length of rolls was ever contemplated until it was found possible to procure, and advantageous to use, plates of such a length. Up to this time the rolling machines in use did not generally exceed 18 feet between the housings. They had been gradually increasing in length ; but now a sudden jump was made in such machines. Nothing less than 25 feet could be entertained. Messrs. Stephen & Sons, of Glasgow, and Messrs. Harland & Wolff, of Belfast, were among the first to order machines of such unusual dimensions. In a few yards are still to be seen machines of smaller size, but if brisker times were to dawn upon the shipbuilding industry there is little doubt that rolling machines of 30 feet or thereabouts would be set up in every yard with any pretensions to enterprise.

A few words as to the design and construction of those bending rolls. It is hardly necessary to say that the

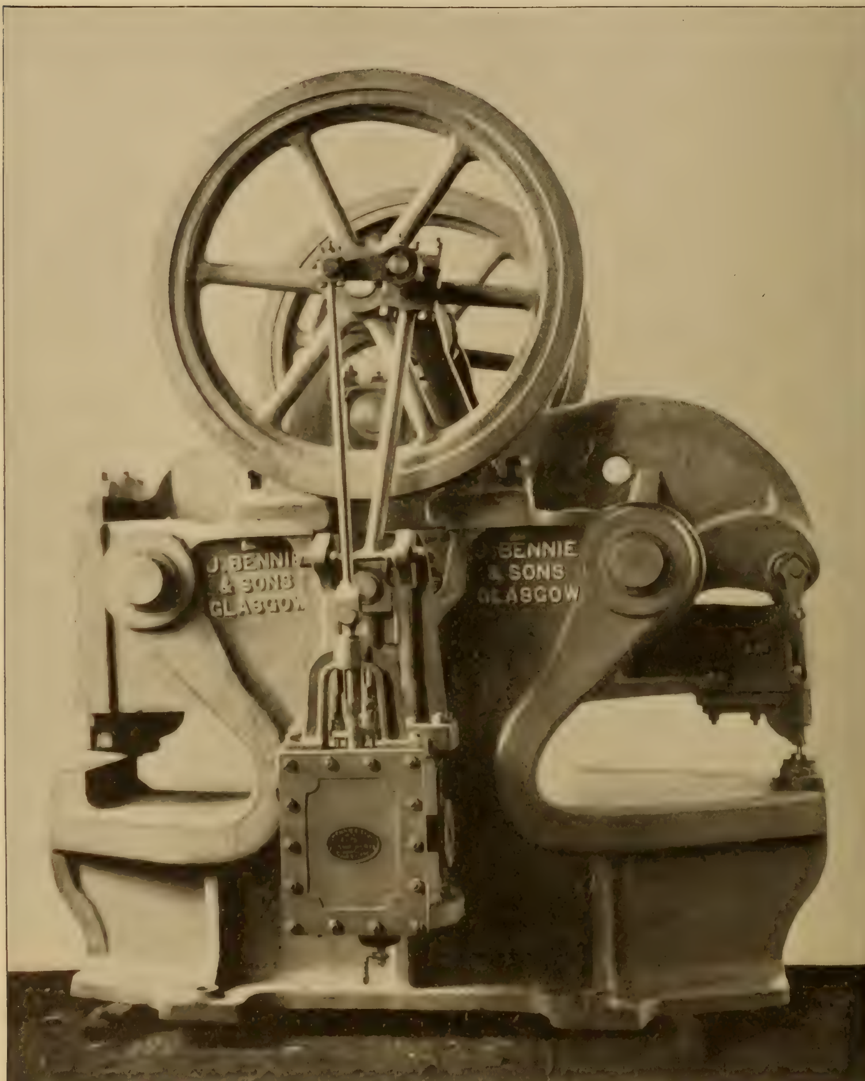
bending, or set, is effected by three rollers, two of smaller diameter below, and one of large diameter above. If a plate is to be bent uniformly to its extreme edge, and as it ought to be, then it becomes indispensable that the lower rollers be of small diameter, so that the centres may be brought as close together as possible. But there is a limit to this. The rollers must have strength enough to bear the great pressure upon them, and that pressure must necessarily increase inversely as the distance of the centres, or bearing points, diminishes. The solution of the difficulty was found in supporting the lower rollers at several parts of their length by several "antifriction" rollers underneath. These supporting rollers had their bearings in the foundation plate of the machine, and not only did these prevent any springing down of the bending rollers while under pressure, but they also reduced the friction of working most materially; for it is plain that if the rollers are kept straight, the end journals are relieved not only of much pressure, but of any tendency to work on one edge of the bearing.

But how about the upper roller? It is movable and cannot be supported easily. Its height varies in working, and sometimes one end is higher than the other, to meet the needs of the plate. Some attempts at supporting the top roller have been tried, but, as a rule, they have not been successful. Their complication and expense nullifies any advantage. It has been found best to make the top roller of very large diameter. For ship work the largeness of diameter in top roller does not detract from its efficiency. There are no small circles to bend. The roller is,



ANGLE IRON PLANING MACHINE, BUILT BY MESSRS. SCRIVEN & CO., LEEDS, ENGLAND.

therefore, made of large diameter and considerable thickness when of cast iron, with a strong steel or wrought-iron shaft throughout. In other cases the top roller has been made an entirely solid forging of wrought iron or steel.



LEVER PUNCHING AND SHEARING MACHINE, BUILT BY MESSRS. J. BENNIE & SONS, GLASGOW, SCOTLAND.

Another question is, how should the bearings of that large roller be formed, so as to adapt itself to the unequal tilting it receives in the exercise of its functions? For it must be borne in mind that one end often requires to be higher than the other. Some makers have contented themselves with simply making the bearing somewhat larger than the axle, and curving it a little, making it convex in fact, to prevent

any jamming. But that is a mere make-shift for cheapness of construction, and is a most unmechanical way of meeting the difficulty. The axle, by that arrangement, can never have a full bearing. The pressure is concentrated on a point, and "seizing" or abrasion is sure to be frequent.

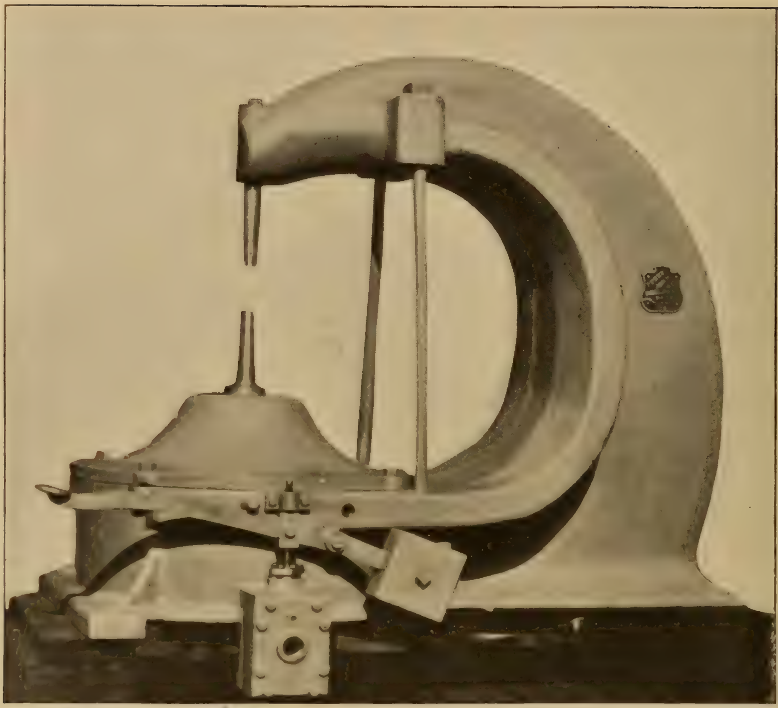
Messrs. Bennie & Sons, of Glasgow, who were the first to introduce the supporting rollers just described, have also designed a special bearing for the axle of the upper roller. It adapts itself to all angles and still maintains a full bearing. The bush in which the axle works is a kind of universal joint, and not altogether so, for that is not necessary. The roller makes no lateral twist; it goes out of line only horizontally. The bush is externally a cylinder, not a sphere, and lies in a cylindrical bearing, the axis of which is transverse to the rollers, and the axle of roller passes through the side of the cylinder. In this form it accommodates itself in the most perfect manner to the axial line of the top roller, however far that may be out of the horizontal. The cylindrical bush simply turns in its seat a little with the axle as that swings out of the level.

Another function had to be provided for in these large rollers. The top roller has to be moved up or down while at work, sometimes at one end, often at both ends; and when its weight did not exceed 6 or 8 tons, it was easy enough to raise it by screws and hand-gear at each end, similarly to the short rolls of the iron rolling mills. But ultimately the enlarged rollers became too ponderous to be quickly raised by hand-gear. Multiplied purchase was too slow, and the number of hands required to work the gear was objectionable.

Messrs. Bennie got over this difficulty in such a masterly way as to render the improvement desirable even in the smaller machines where the hand-gear was serviceable. They were the first to apply belt power gear with friction clutches for raising and depressing the top roller. This improvement, as regards facility of working, was one of the most important effected on the rolling machine. If the shell plates could receive the required curve by being put through the rolls endwise, instead of sideways, a great saving in first cost and in room might be realized. Mr. H. O. Bennie has aimed at this in a machine which he designed and patented about a year ago. Whether his firm ever succeeded in putting that idea into a workable shape is not known to the writer, for up to this time no such machine seems to have been put upon the market. But a reference to the patent specification shows a design of considerable ingenuity, and with some modifications towards simplicity it might be made quite practicable.

It seems in its conception to embrace more complication in details than is allowable in a machine that is to be handled by rough, and, in many cases, unskilled workmen. But it is a combination that may be licked into proper shape by and bye. Here it may be affirmed that simplicity and strength are indispensable in shipyard tools. Refinements of mechanism are quite out of place. In an open yard, where dust and grit are abundant, where the workmen are little better than unskilled labourers, where work has to be pushed through "by the piece," not to accord with the sublime notions of an æsthete, the machine-tools cannot be too simple or too easily understood. When they break down, or get out of order, they must be easy of repair, by the rudest of workmen. If they do not fulfil these conditions they ought not to be in a shipyard.

A workman sometimes attempts to exact services from these machines, for which they were never designed. He wants a thick washer with a small hole in it, and he brings to the punching machine a piece of plate thicker than the punch will go through; or he brings a piece of steel plate that has been hardened by sudden quenching in water. Lucky he is if only the punch crushes, without a general break-up of the machine. Or, he brings a bolt having a large head, which he attempts to cut off at the shears, never looking to see



A STEAM RIVETER, BUILT BY THE PUSEY & JONES CO., WILMINGTON, DEL., U. S. A.

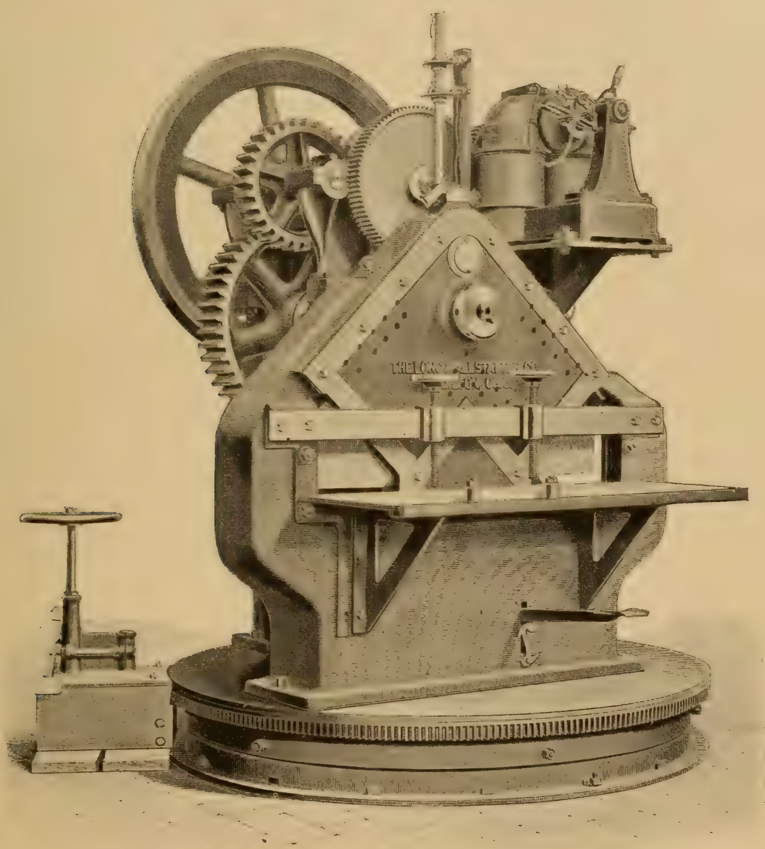
whether there is room for the head when the slide comes down. In truth, it would be well if all such tools were provided with some simple breaking part, easily renewable,—that part to be strong enough to do the maximum of fair work, but weak enough to yield when some uncalled for stress was brought upon it. Relief of this kind has sometimes been provided for in the make-up of punching and shearing slides, where some part, of simple form and easy renewal, is designed to give way at a given pressure, and thus save the excentric end of a main shaft, the fracture of the main casting, or the destruction of a train of wheels and pinions, and perhaps injury to the men in its neighbourhood.

The next, if not the chief, in importance is the punching press. This machine is still indispensable in the shipyard. However preferable drilled holes may be in certain kinds of work,—such as girders and bridges, where several layers of plates are often united by through rivets, and where it is important that the holes should be perfectly coincident and fully filled up by the rivets,—drilling has not yet superseded punching for the plates and angles used in the construction of a ship. The process, even in the best of drilling machines, is much too slow, and even if drilling could compete with punching as regards rapidity, it is questionable whether the work would be as good.

A good drill makes a hole truly parallel, from its entrance till it passes out through the other end of the hole it has formed ; and it cuts away the metal without injuring or disturbing the molecular arrangement of the metal around the hole. The parallelism of the hole is an advantage, particularly in the case of holes pierced through several layers of plates. But it is doubtful if it is any advantage to have single plates, or plates and angles united by rivets through drilled holes, as shall be shown farther on.

The other advantage claimed for drilling,—that of having no deteriorating influence on the metal surrounding the hole, is undeniable. The tenacity of the piece drilled is not affected, except to the extent of the area of metal removed from its section. Now, it is well known, and proven by experiments, that the punch has a weakening influence on the metal surrounding the holes punched in plates of inferior quality, or wrought iron of a brittle nature, not far removed from cast iron in its character. But it has been found that the portion of material weakened around a punched hole extends only a very little depth, and this impaired portion is usually removed by the rymering or countersinking, which all holes in shell plates undergo. It is still questionable whether the punch, by the forcible detrusion of the metal, has any such evil effect on soft, or thoroughly ductile wrought iron, as Lowmoor or other good Yorkshire brands, or on steel plates as now manufactured,—mild and ductile as lead.

If experiments have shown any difference in strength between punched and drilled structures of mild steel plates, that difference is so slight as to be hardly worth taking into account, when we set against it the many advantages which punching confers. And that difference, if any, exists only in the case of punched plates that have been



AN ELECTRICALLY DRIVEN ANGLE IRON SHEAR, BUILT BY THE LONG & ALLSTATTER CO., HAMILTON, O., U. S. A.

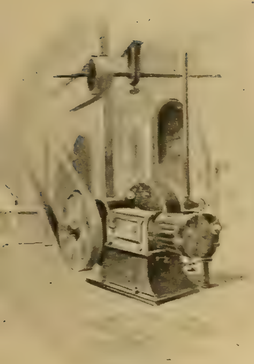
riveted together without the holes being rymered. That the punch does not make a parallel hole is an advantage in all ship work. It can punch parallel holes only with a difficulty that is dangerous to the punch or machine. The diameter of the die hole ought always to be a little greater than that of the punch. The consequence of that difference in diameter between punch and die is that the punched hole on the die side is a little larger than on the side which the punch entered. In short, the hole is tapered, or conical, and the degree of taper is regulated by the difference in diameters of punch and die. The larger the die hole is, the more easily is the piece of metal detruded, and the greater the degree of taper.

This taper, as it comes from the punch, is regarded by practical men as an advantage in some structures, such as boilers, when only two plates are riveted together. When the plates are united with the wide ends of the holes outermost there is a distinct advantage, particularly where the rivets are closed up by hydraulic pressure, and thus made to fill up the holes. There is thus formed a secure junction, independently of the head, which may be formed at the end of the rivet. If the head made by riveting were broken off, the rivet would still keep its place and hold the joint. There is no such advantage in a parallel hole. Moreover, the sharp edges, which are left by the drill, not only makes the rivet-heads more liable to break off, but help also, in some degree, to facilitate the shearing tendency to which nearly all riveted joints in steam boilers are exposed. In shipbuilding, the taper of the holes is advantageous, and it is always increased by a conical or countersinking drill, for no rivet heads are allowable on the outside of a ship. The rivets are all compressed into the conical hole until "flush" with the surface of the plate, and thus the rivets, by their taper, hold the plates together.

Unquestionably when drilling can be done *in situ*—after the plates are put together, there is a certainty of getting holes to go straight through the layers of plate without the need of resorting to the pernicious practice of drifting. Half blind holes can never be made to coincide by the drift It is but a rough and violent expedient to make a bad hole take a rivet, and it is to be hoped that its use is now altogether prohibited. If drilled holes could have their sharp edges removed and a slight taper imparted where necessary, then drilling would be superior to punching. But drills have not yet been made that can be conveniently brought into action on a ship's side, and do the work quickly enough. Until some such tool is available, the punching machine will be found the readiest and most economical rivet-hole maker for shipbuilding.

A STEAM PLANT FOR A SMALL ELECTRIC LIGHT AND POWER STATION.

By Professor R C. Carpenter.



THERE are very many classes of engines and a still greater variety of styles and patterns of design, so that the designer who desires to select an engine is more likely to be embarrassed by the multiplicity of forms offered by various manufacturers than by any scarcity either in form of type or variety of styles submitted.

The power which is needed must be one that will meet the following requirements :—first, certainty and reliability of operation ; second, regulation for varying conditions of load ; and third, economy of operation. So far as certainty of operation is concerned, there is not perhaps a very great difference in the various styles and makes of engines, but there is a great difference in the character of the speed regulation and a still greater difference in the economy or relative cost of operation.

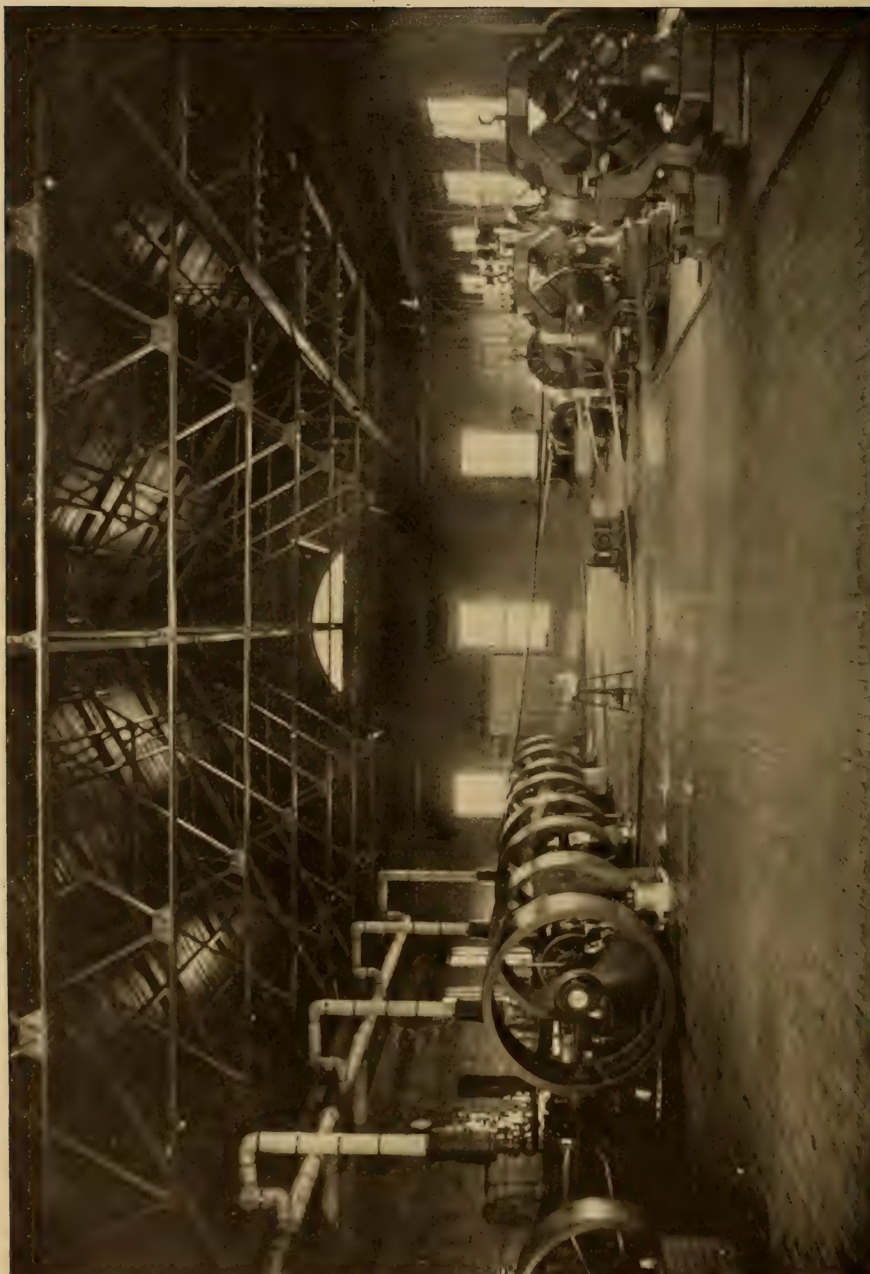
The engines of American build which compete for favour in this field of work, can be classified in several ways ; first, as to the method of governing, as throttling, automatic or drop cut-off ; second, by the number of cylinders through which the steam passes in succession, as, simple, compound, triple expansion, etc. They are also sometimes classified by the relative speed of rotation as high speed and slow speed.

Any of the first class of engines can be built simple, compound or for triple-expansion, as required. Regarding the various types of engines which are classified by the method of governing, it may be said briefly that the engine with a throttling governour is, in most respects, practically the same as that built by James Watt. In this engine, the governour is independent in construction of the engine, and is generally operated by a belt, running over the main shaft.

The throttling governour consists of two or more balls which swing in horizontal or vertical plane, and move by the change of centrifugal force in such a manner as to partly or wholly close a valve in the main steam supply pipe. The action of the governour is to reduce the amount of steam which passes into the steam cylinder, thus causing a certain portion of the expansion to take place before reaching the engine. The engine operates with a fixed eccentric which produces in every case a uniform position of cut-off.

In the United States this style of construction has generally been limited to a very cheap and poor grade of engines, and for this reason a great deal of prejudice is felt respecting engines which are governed by throttling. The regulation or uniformity of speed with varying loads which it is possible to maintain with the throttling engine may be good, but the experience with the engines of this kind would indicate that no matter what might be the highest attainable possibility, practically they have failed to meet even moderate requirements for good regulation.

The engines termed "automatic" are regulated by the variation in travel of a slide valve, which moves so as to open the ports as required



THE ENGINE ROOM OF THE CORTLAND HOMER TRACTION CO., CORTLAND, N. Y. U. S. A.

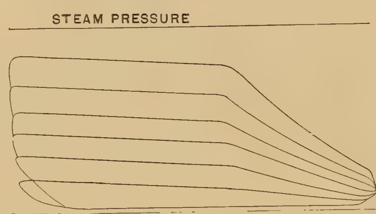
to produce uniform speed. This is accomplished by attaching the valve rod to a rotating or swinging eccentric, which is moved directly by the governour. The latter consists of balls, fastened on one or more levers, and is located in the fly-wheel; the excess of centrifugal force produced by increase in speed is overcome by springs. This governour, from its position, is termed the shaft governour, and the regulation attained with some of these governours with variations of load of extreme amount has been remarkably close.

The variation in speed during the extreme range in load with this class of engines is usually less than one per cent., and with many of them, less than one-half that amount. The valve employed in the automatic type of engine is either a round or flat slide valve which moves beneath plates, placed in such a manner as to remove most of the steam pressure from the valve, and because of this construction it is termed a balanced valve. The engines of this class generally run at a high speed,—from 150 to 300 revolutions per minute,—and ordinarily they have a comparatively short stroke with reference to the diameter of the cylinder, and quite large clearances. They rank higher than the throttling engine in economy, but not so high as those of the drop cut-off type.

From a study of the results of numerous tests of this type of engine, the writer is inclined to believe that the principal defect or weakness likely to occur is that due to leaky valves. In an engine of this type it is desirable that the valves shall move very easily, otherwise the regulation will be poor, and, in satisfying this condition, the valve is likely to be fitted so as not to be perfectly tight. It is quite probable that the principal reason for this class of engines falling in economy below those of the drop cut-off type, is due to the fact that slight leakages at the valves are hard to prevent.

There is a difference of opinion held regarding relative economy of engines, operating with fixed and variable cut-off. In the first class, regulation is obtained by reducing the steam pressure, and in the second class, by increasing the number of expansions. These are well shown in the several indicator diagrams on this page. In the throttling engine, the loss due to cylinder condensation is a smaller percentage than in the other because of the later cut-off. In the variable cut-off engine the increased percentage of cylinder condensation is offset by increase in number of expansions.

It is difficult to make comparisons of the relative economy of these two



THROTTLING GOVERNOUR WITH VARYING LOADS.

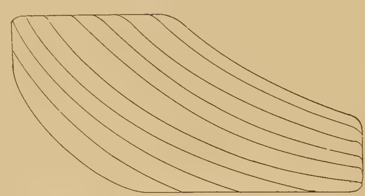


FIG. I. AUTOMATIC GOVERNOUR WITH VARYING LOADS.

types experimentally, because of the difference in construction of the two engines and the difficulty of eliminating all other variable conditions. The writer once made a test of two engines practically of the same size, the one a throttling engine, and the other automatic, operating alternately on the same work and in competition. Both engines were in excellent condition. The steam pressure was the same, and the only essential difference was in the speed of rotation, which was considerably greater in the automatic than in the throttling engine. The test always seemed a fair one to the writer, and it showed a result in favour of the automatic engine of about 15 per cent. of the total. From theoretical considerations, however, no difference could be expected when both

engines were operating at the best number of expansions.

The general form of curve which indicates the total steam consumption for varying loads is different with these two classes of engines, and is well shown in Fig. 2, which represents the results obtained by actual test with the same engine when regulated by a throttling governour and with an automatic governour. It will be noticed that the difference is not great, and, for light loads, is in favour of the throttling engine; but

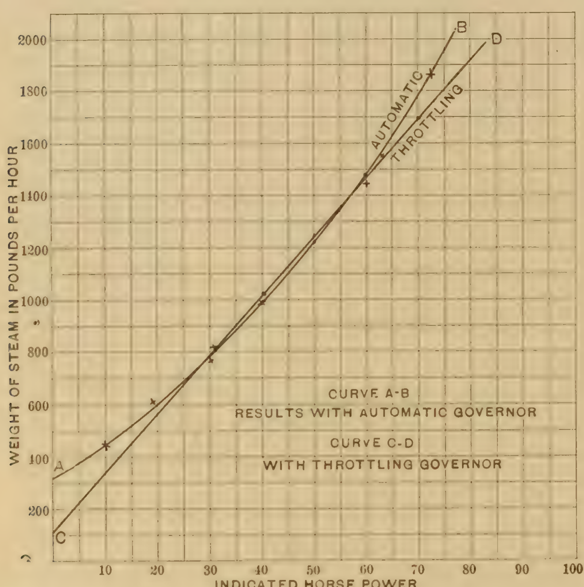


FIG. 2. DIAGRAM SHOWING TOTAL WATER CONSUMPTION OBTAINED BY TESTING THE SAME ENGINE WITH A THROTTLING GOVERNOUR AND WITH AN AUTOMATIC OR A DROP CUT-OFF GOVERNOUR.

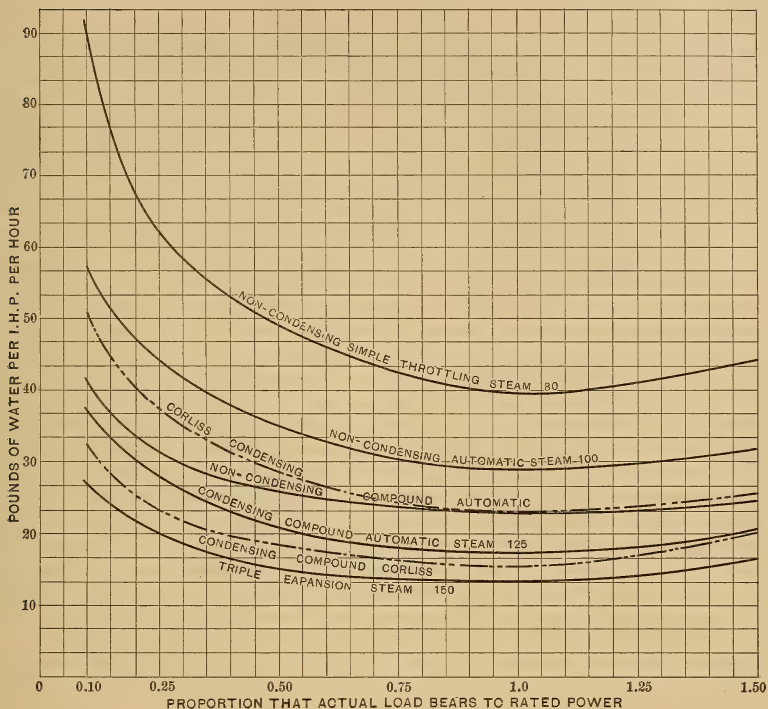
for the intermediate loads it is in favour of the automatic. The form of the curve is also different, being practically a straight line for the engine with the throttling governonr, and a curved line for the engine with the automatic govvernour.

Several engines of the drop cut-off type are made, and of these the Corliss is the best known and most widely used. In this class of engines the speed of rotation is comparatively slow, but the piston speed is not essentially different from that in the other type of engines. The valve has a rotary motion over the port and is moved by a fixed eccentric, which connects by a valve rod with a rocker arm, which, in turn, connects by a rod with the valve. The governour acts to release the valve from its connection with the valve mechanism, in which case it is closed very suddenly, either by a spring or a dash pot.

This class of engine, without doubt, represents the most economical type on the American market. The regulation obtained can hardly be said to equal that obtained with the shaft governour, but it is generally close enough to meet all requirements likely to be made.

The problem which the designer of a steam plant for an electric station has to consider is rendered difficult of solution from the fact that the amount of work which is to be performed by the engine is, to a great extent, uncertain in character and extremely variable in quantity. The effect which a variable load has on the economy of an engine has been investigated many times, and the results accord with practical unanimity in showing that the amount of steam required for a unit of power increases rapidly with the diminution of load.

Tables I and II and Figs. 3 and 4 were obtained by a comparison of a large number of experiments, and will be found to be valuable in predicting what may be expected of the various classes of engines. They are based on the relative condition of loading, which the writer considers rather more convenient in practical application than the number of expansions. The full load to which reference is made is essentially the same as that for which the engine is rated, since the practice of most manufacturers in rating their engine is uniform, and usually such that full load is expected with from three to four expansions in a simple engine, eight to ten expansions in a compound engine, and sixteen to twenty expan-



Rated power is that given by a simple engine with 3.3 expansions; by a compound non-condensing with 8 expansions; by a compound condensing, with 10 expansions, and a triple expansion condensing, with 16 expansions.

FIG. 3. CURVES OF PROBABLE WATER CONSUMPTION PER I. H. P. PER HOUR FOR VARIOUS CLASSES OF ENGINES WITH DIFFERENT LOADS.

sions in a triple expansion engine. The curves in Figs. 3 and 4 show the water consumption per indicated horse-power for different loads. These vary with the class of engine, being more nearly straight as the economy of the engine is higher.

The writer has a theory for these curves, which may be stated as follows :—With a perfect engine no steam would be used for any purposes but for performing the work, and hence, there would be no wastes due to radiation and condensation. For the perfect engine, it is entirely possible to compute the weight of steam that would be required for any given steam pressure or exhaust pressure. In such an engine, there being no wastes and all the heat within the given range of temperature being converted into work, the amount of steam which would be required per unit of work, must, in every case, be constant and independent of the work performed or the number of expansions.

The actual engine requires more steam than the perfect engine when working at the best ratio of expansion, because of the inevitable waste of heat which takes place. The fact that when working under one set of conditions, an engine requires more steam per unit of work than when working under another set, indicates that the wastes are greater. These wastes are principally those due to cylinder condensation and are greatest at the beginning of a stroke. Numerous experiments have been made to determine the amount of this waste, and while these experiments are not in every respect harmonious, they agree in showing a great increase for small loads and high ratios of expansion. By collecting and

TABLE I.

Probable Water Consumption per Indicated Horse-Power per Hour for Various Classes of Engines with Different Loads.

Class of Engine.	Gauge Pressure.	General Equation of Steam Consumption.	Ratio of Load to Rated Capacity.						
			1-10	¼	½	¾	1	1¼	1½
		Value of x.	10	4	2	1.33	1	1.25	1.50
			Lbs. of Water per I. H. P. per hour.						
Throttling. . Non-Condens'g	80	$22.2\sqrt{x}+17.8$	88.8	62.2	49.6	43.7	40.0	42.8	45.2
Automatic. . "	80	$14.2\sqrt{x}+17.8$	63.0	46 2	37.9	34.2	32.0	33.7	35.2
" "	100	$12.9\sqrt{x}+16.1$	56.8	41.9	34 4	31.0	29.0	30.5	31.9
Corliss Simple "	80	$12.2\sqrt{x}+17.8$	56.4	42.2	35.1	31.9	30.0	31.5	32.8
Compound Automatic "	100	$9.8\sqrt{x}+16.1$	47.1	35.7	30.0	27.5	25.9	27.1	28.1
" " "	125	$8.6\sqrt{x}+14.4$	41.6	31.6	26.6	24.3	23.0	24.0	24.9
Corliss Simple . Condensing	80	$13.7\sqrt{x}+9.3$	51.5	36.7	28.7	25.1	23.0	24.6	26.1
Compound Automatic "	100	$10.2\sqrt{x}+8.8$	41.0	29.2	23.2	20.6	19.0	20.2	21.3
" " "	125	$9.2\sqrt{x}+8.3$	37.3	26.7	21.3	18.9	17.5	18.6	19.6
Corliss Compound "	100	$8.7\sqrt{x}+8.8$	36.4	26.3	21.1	18.8	17.5	18.5	19.5
" "	125	$7.7\sqrt{x}+8.3$	32.7	23.7	19.2	16.6	16.0	16.9	17.7
Triple Expansion	125	$6.2\sqrt{x}+8.3$	27.9	20.7	17.1	15.5	14.5	15.2	15.9
" "	150	$5.85\sqrt{x}+7.9$	26.4	19.6	16.2	14.6	13.75	14.4	15.1

NOTE: x = actual horse-power divided by rated horse-power.

TABLE II.

Probable Water Consumption per Delivered Horse-Power for Various Classes of Engines with Different Loads.

Class of Engine.	Gauge Pressure.	[1] Ratio of Indicated Load to Rated Power.						
		1-10	¼	½	¾	1	1¼	1½
		Lbs. of Water per Delivered H. P. per hour.						
Non-Condensing.								
Throttling Simple.	80	Friction Load D. H. P. = 0.	103.	74.5	50.5	44.5	46.6	48.5
Automatic "	80		77.0	47.5	39.6	35.6	36.6	37.8
" "	100		70.0	43.0	35.8	32.3	33.2	34.2
Corliss "	80		70.5	43.8	36.8	33.4	34.2	35.2
Automatic Compound	100		59.5	37.7	31.8	28.8	29.4	30.1
" "	125		52.7	33.3	28.1	25.6	26 1	26.7
Condensing.								
Corliss Simple	80	Less than Friction Load.	73.4	38.3	30.1	26.3	27.4	28.5
Automatic Compound	100		58.4	31.0	24.8	21.7	22.5	22.2
" "	125		53.4	28.5	22.7	20.0	20.7	21.4
Corliss "	100		52.6	27.2	22.6	20.0	20.6	21.2
" "	125		47.4	25.6	19.9	18.3	18.8	19.3
Triple Expansion	125		41.4	22.8	18.6	16.6	16.9	17.3
" "	150		39.2	21.6	17.5	15.7	16.0	16.5

[1] The numbers express the proportion of the indicated horse-power developed to the rated indicated horse-power.

comparing a large number of these experiments, the writer found that they could be expressed in the form of an equation,

$$y = p + b\sqrt{x}$$

In this expression, y represents the probable water consumption of an engine per indicated horse-power per hour; p, that of a perfect engine, working with the same range of temperature; x, the ratio that the rated power bears to the actual power when the engine is under-loaded; and the reciprocal of this quantity when the engine is over-loaded; b is a constant, determined by experiment, and is the difference between the steam required per horse-power under best conditions by the perfect and the actual engine.

As an illustration showing the use of the formula, we will consider the case of a simple Corliss engine, working with steam pressure of 100 pounds and exhausting into the air. For this case the perfect engine requires 17.3 pounds of steam; the actual engine with best load, requires 10 pounds more, so that for this engine, b would equal 10, p would equal 17.3; at one-half load, x would equal 2; at one-quarter load, x would equal 4; and at one and one-half load, x would equal 1.5. By substituting these values we should obtain results which would be very close indeed to that obtained by the actual engine working under varying conditions. The curves which are given in Fig. 3 can be taken as representing very fairly the consumption per unit of indicated power for the various classes of engines and will thus afford valuable assistance in determining the class of engine to be employed.

The maximum power which must be provided can usually be obtained at least approximately, from the amount of work which is to be accomplished.

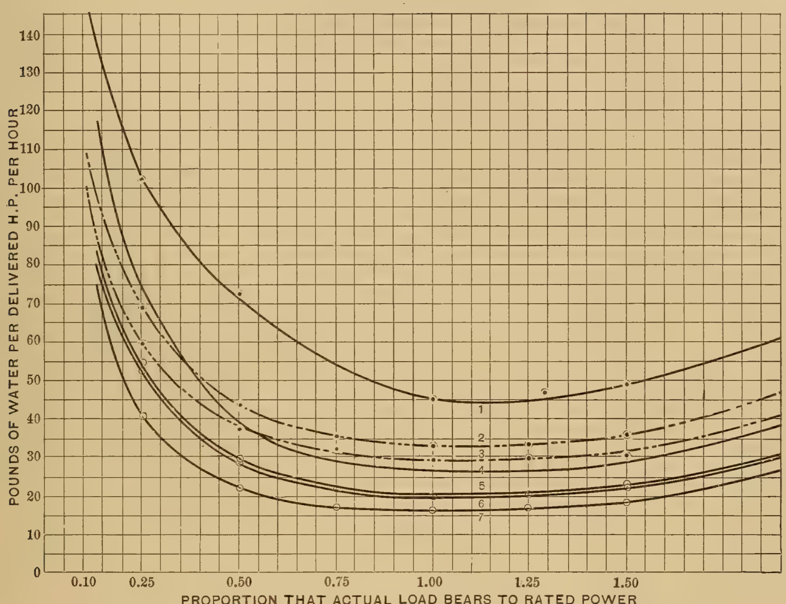


FIG. 4. PROBABLE WATER CONSUMPTION PER DELIVERED HORSE-POWER.

Curve No. 1.	Non-condensing	simple throttling, steam		.....	80
" " 2.	"	" automatic	"	.....	100
" " 3.	"	" compound automatic	"	.....	125
" " 4.	Condensing, Corliss			.....	80
" " 5.	"	compound	automatic	.....	125
" " 6.	"	" Corliss	"	.....	100
" " 7.	"	Triple expansion	"	.....	150

THE BOILER ROOM OF THE CORTLAND HOMER TRACTION CO.

Thus, if it be for a lighting station, the plant will be intended for a certain number of incandescent and arc lights as a maximum. If for electric railroad purposes, the plant will be installed with sufficient power for running a certain number of cars of known capacity or weight at definite rates of speed. There seems very little practical difficulty in obtaining these values. The problem which comes to the designer of the power plant is usually that of providing the most economical plant possible when conditions of operating expense, interest, etc., are considered. The requirements are to provide a specified amount of power, to be used either in railroad work or in lighting.

We can assume that the maximum amount of power which must be provided is known from the data given, and engines must be provided with sufficient capacity to meet this condition. The average, however, is likely to be very much less than the maximum and is known only approximately. In the case of an electric railroad where a constant number of cars are in service, the load is likely to vary from the maximum to the minimum at any instant, and without previous warning. The interval of time between the recurrence of maximum and minimum conditions of loading is often very small.

Whether an engine is rendered less economical in operation by these great fluctuations of load than under the condition of steady running with a load equal to the average throughout the test, the writer is unable to say positively ; but there is probably some loss, due to the varying number of expansions and to the slight variation in speed which is likely to follow consequent upon the change of load.

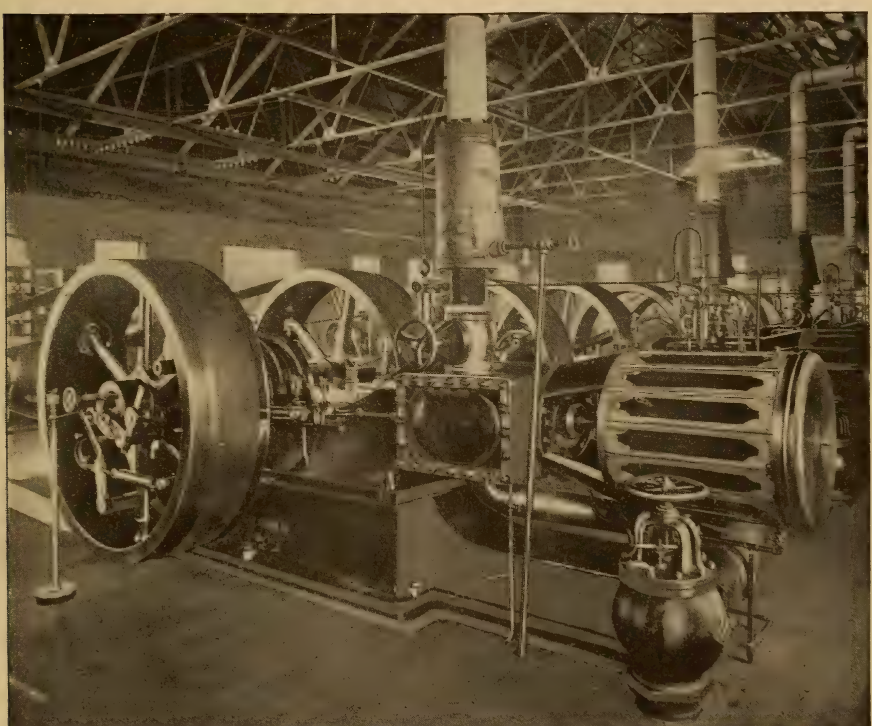
The power for electric lighting is likely to vary gradually and to pass through a condition of maximum and

minimum loads at certain hours of the day with a regularity which can be depended upon and for which provision can be made in advance. This will depend, no doubt, upon the peculiar conditions surrounding the plant, and is well illustrated in Fig. 5, which represents the power required in three large stations. The dotted lines show the output of each station; the full line, that of the total.

The elements of cost which determine the economy of a given type of station are made up of the sum of the interest charges for plant and building, the cost of fuel, repairs and attendance. In general, the more economical plant will cost more for installation than the less economical one; this is subject to limitation from the fact that the more economical engine requires considerably less steam and consequently it may be supplied by a smaller boiler.

The costs of a steam plant are not exactly proportional to the power required, as the large engines are proportionately cheaper than the small ones, but, considering a plant for a given power, we can obtain figures which will serve as a fair basis of comparison. It will be found that the ordinary simple engine requires very nearly, if not quite, one boiler horse-power for each horse-power of work performed, while the compound engine requires from five-tenths to six tenths as large a bo ler, and the triple expansion from four-tenths to five-tenths.

This reduction in size of boiler often serves to offset the extra cost of the more economical engine. Thus, as an illustration, applying to engines of about 150 horse-power capacity, a simple automatic engine would cost \$12.50 (£2. 10s.) a horse-power; a simple Corliss engine, \$15.00 (£3) a horse-power; a compound automatic, \$15.00 (£3) a horse-power; and a compound



ONE OF THE WATERTOWN ENGINES IN THE STATION.

Corliss engine, $22.00 (£4. 8s.) a horse-power. A common tubular boiler with brick setting would cost $15.00 (£3) per horse-power, and a water-tube boiler, $24.00 (£4. 16s.) The table on the opposite page gives the various elements relating to installation and operation.

The costs were obtained by consulting estimates actually made by builders of the various kinds of engines and are believed to represent, very fairly, the average price at the present time. These are, however, likely to vary, with times and circumstances, 10 to 20 per cent. from the amounts given. In the totals which are given, the price of a chimney is omitted for the reason that this would vary greatly, depending upon the material used and the method of construction, and is not likely to differ materially for any given kind of plant.

The cost of buildings is made to vary somewhat in proportion to the room required by the various engines. This is a quantity which will also depend very much upon local conditions and upon the sentiments of the board of directors paying the bills. Stations have been erected in which the cost of the building was fully equal to that of the steam plant. Such a construction can hardly be considered necessary, and is not often required.

By referring to the curves showing relative economy of the various engines with varying loads, it will be noticed that the more economical engines are less affected by change in load than those which are less economical, and this affords another reason for the use of a compound instead of a simple engine where the load is extremely variable in amount.

The actual economy which has been obtained in plants for electric railroad work has, for the reasons mentioned, not been high, the results of actual tests showing a consumption of coal 50 to 75 per cent. higher than would have been expected with the same engines running under the best conditions. With electric lighting stations, the same practical results are shown. This is well illustrated by Fig. 6, which shows the consumption of coal for both the total output in kilo-watts and for the output per kilo-watt-hour for one of the prominent illuminating companies of Boston. A kilo-watt corresponds to about 1⅓ horse-power, and it will be noticed that the coal consumption varies from 11 pounds per kilo-watt to 30 pounds, depending upon the load. This means that the coal consumption per I. H. P. probably varies from 5 to 15 pounds per hour.

We have briefly pointed out the difficulties and some of the causes which prevent the securing of high economy in power stations for electric plants, and which can be considered as explaining the reason why unfavorable results are obtained. We will next consider methods which possibly might tend to increase the economy. Most of the evils which cause low economy are due to the fact that engines are operated with a very light load. The obvious remedy for this difficulty, then, must be to so modify the design that engines can be operated for a greater portion of the time with a full load. This may be solved, in an approximate manner at least, by employing a number of small engines, which are successively put in operation with the demands for increased power.

Where the variation in load is quite regular and the change gradual, as illustrated in Fig. 5, this scheme can be applied very nicely and will give fairly good results. By consulting the curves given in Fig. 3, it will be seen that the economy which may be obtained with engines of the poorest type, when fully loaded, is better than that which may be obtained with engines of the best type having a very light load, so that it is better to suffer from the losses of several small engines which work with fairly good loads, than those from one large engine operating with very light loads.

For an electric railroad station where there is no regular periodic variation, this method will not give satisfactory results, since the change of load from maxima to minima is almost instantaneous and often varies several times per

TABLE III.

Costs of Different Types of Engines.

Kind of Engine.	Elements of Cost.							Yearly Costs.			
	Steam Pressure.	Water per I. H. P. per Hour.	Water per D H. P. per Hour.	Best No. of Expansions.	Boiler H. P. per I. H. P.	Coal per H. P. Hour Evaporation, 7 lbs.	Tons of Coal per Year of 30. 0 Hours.	Interest at 10 Per Cent.	Coal at $2.00.	Coal at $3.00.	Coal at $5.00.
Non-Condensing. *Simple.*											
I. Throttling	80	40	44	3	1.33	6.3	9.15	3.85	18.90	28.35	47.20
II. Automatic	to	31	34	3.3	1.03	4.9	7.35	4.10	15.70	22.05	36.75
III. Corliss	100	28	31	4	0.93	4.4	6.60	4.99	12.20	19.80	33.00
Compound.											
IV. Tandem high-speed	120	25	28	8	0.84	4.0	6.00	4.21	12.00	18.00	30.00
V. Cross "	to	25	28	9	0.84	4.0	6.00	4 66	12.00	18.00	30.00
VI. Cross Corliss	150	24	27	9	0.80	3.9	5.85	5.40	11.70	17.55	29.25
Condensing. *Compound.*											
VII. Tandem high-speed	120	18	21	10	0.60	3	4.50	4.55	9.00	13.50	22 50
VIII. Cross "	to	18	21	10	0.60	3	4 50	5 05	9 00	13.50	22 50
IX. Corliss	150	16	19	12	0.54	2.7	4.05	6.31	8.10	12.15	20.25

Costs per I. H. P. for a 600 H. P. Plant.

	.	Engine.	Foundation.		Piping.	Condenser.	Boiler, Tubular, at $15 00.	Building.	Total Cost per I. H. P.	Interest and Coal at $3.00.	Interest and Coal at $5.00.
Non-Condensing. *Simple.*											
I. Throttling	---	10	1.50	----	2.00	----	20.00	5	38.50	32.20	52.05
II. Automatic	---	12.50	2.00	----	2.00	----	18.50	6	41.00	26.15	40.85
III. Corliss	---	15.00	4 00	----	2.00	----	13.90	10	44.90	24 79	37.99
Compound.											
IV. Tandem high-speed	---	15.00	2.50	----	2.00	----	12.60	10	42.10	22.21	34.21
V. Cross "	---	18.00	4.00	----	2 00	----	12.60	10	46.60	22 66	34.66
VI. Cross Corliss	---	22.00	6.00	----	2.00	----	12.05	12	54.05	22.95	34.65
Condensing. *Compound.*											
VII. Tandem high-speed	---	15.00	3.00	----	3.00	3.00	9.00	12.50	45.50	18.05	27.05
VIII. Cross "	---	18.00	5 00	----	3.00	3.00	9 00	12.50	50.50	18.55	26.25
IX. Corliss	---	22.00	7.00	----	3 00	4.00	8.12	20.00	63.12	18.46	27.06

second. For this case it has seemed to the writer that the most satisfactory method was the use of an engine so small that it should be operated in the condition usually considered an overload when meeting the maximum requirements for power.

To meet this condition, the working parts of the engine such as piston-rod, crank pin, main shaft, etc., must be made heavier in proportion to diameter of cylinder than has been the usual practice. As an example to meet this condition we would use an engine cylinder of such a size that at four expansions it would be rated at 150 horse-power on an engine which is expected to work at times to 200 horse-power. This requires an engine, with the valves so designed that, when necessary, steam can be taken for nearly the whole stroke of the piston, and the working parts of the

engine must be sufficiently heavy to withstand all the strains and stresses caused by sudden applications of this load. This engine would not give highly economical results when fully loaded, nor when running very light, but the average result would be better than that obtained by an engine with a larger cylinder.

For suburban work, or electric railroads in small cities, a generator of 100 kilo-watt capacity is much used. The recent types of this machine are well built and will run for a considerable time without injury, at 25 and even 50 per cent. overload. Such a machine will furnish current sufficient to run from eight to ten cars, depending upon the length of line, grades, character of construction, etc. An engine of 150 indicative horse-power, would deliver 135 to 140, under ordinary conditions, and would drive a generator of the kind mentioned under all conditions of loading.

Where the service requires a large number of cars, the variation between maximum and minimum load occurs at less frequent intervals, and larger generators and engines should be used. To lessen the liability of accident, more than one generator is necessary, and it will generally be productive of better results to provide two machines and two engines of small capacity, rather than only one of large capacity. It is quite true that the multiplicity of small machines adds somewhat to the operating expenses, but the provision against a "complete shut-down," due to an accident to a single machine, is likely to more than compensate for the extra costs of operating.

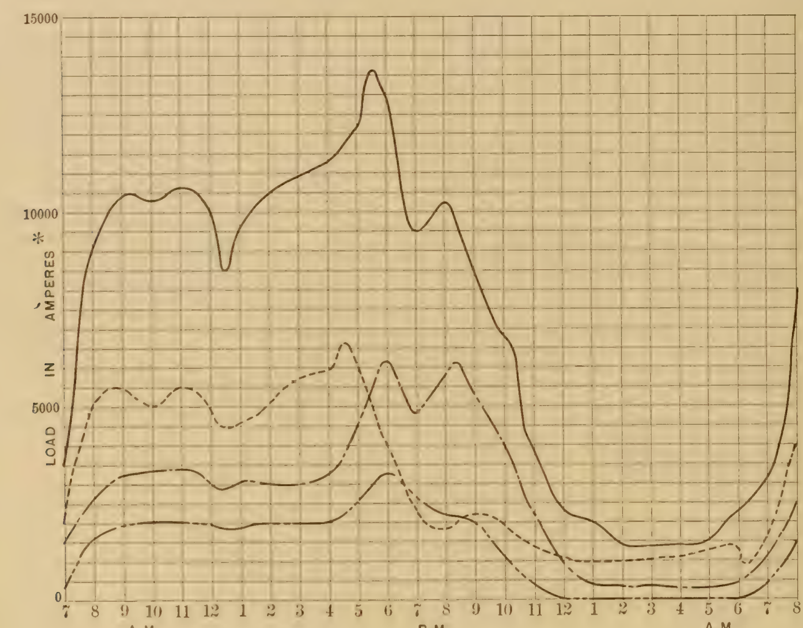


FIG. 5. LOAD DIAGRAM IN ELECTRIC STATIONS.

As a practical illustration of the various considerations mentioned, an actual case will be taken up. The problem may be stated as that of, providing a power plant for an electric railway and a lighting station combined, in a small city where the distances are great and the total amount of patronage expected, small. The lighting company had been in existence for some time and already possessed two engines of 60 horse-

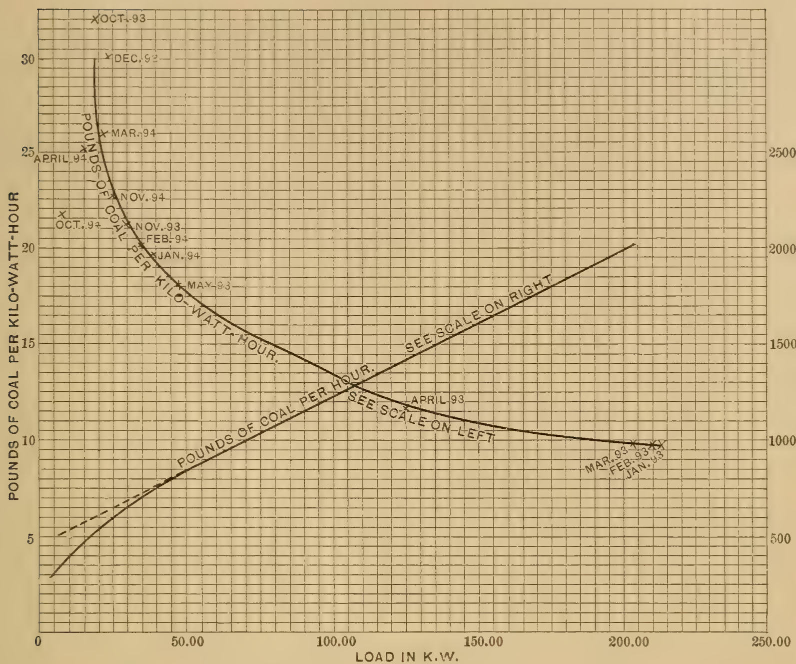


FIG. 6. ACTUAL RESULTS OF TEST OF A LARGE LIGHTING STATION.

power each, and several, very dilapidated electrical machines. The electric railroad was a new venture and the design could be made complete and unhampered by old machines.

The total length of railroad to be installed was to be about ten miles. The ordinary service would require six cars, and the maximum service for which power had to be provided was ten cars. The lighting was estimated as requiring a maximum of 400 horse-power, and, to meet this demand, it was finally decided to purchase new engines, retaining the old ones already owned by the company for day-use, or when the demand for current was very small.

It was finally decided, after considering all questions, to install a direct-belted plant, the power part of which should consist of four engines of the same size and make, and as nearly alike as possible, each having a capacity of about 175 horse-power when working with about five expansions. One of the four engines would stand as a relay, ready for use in case of an accident to any other engine. The electrical machines were to be so arranged with reference to an over-head track, that in case of any accident they could quickly be shifted so as to be operated by any engine. The system of operating the dynamos by direct belting was adopted, although the writer is of the opinion that under present conditions of manufacture, a system of directly connected generators, which might have been installed at a slight additional cost, would have better answered the requirements.

Compound condensing engines of the tandem automatic type, of very heavy pattern, were adopted as best meeting the requirements of moderate first cost and reasonable operating expenses. The specifications were so drawn as to afford free competition from a certain number of reputable builders, and the number who were invited to make proposals for the work was limited to those who were believed to build engines of essentially the same quality.

In the first considerations it was pro-

posed to locate the plant in some buildings already owned by the company, in which case it was intended to use water-tube boilers. These old buildings, although on the trolley line, were some distance from a steam railway and could be made useful as shops and car sheds. The question of obtaining a plentiful supply of condensing water was also uncertain in that locality. These considerations finally led to the location of the power house on a small piece of land situated near a river, and from which condensing water could be obtained. The new location was also adjacent to a railroad track from which coal could be readily delivered.

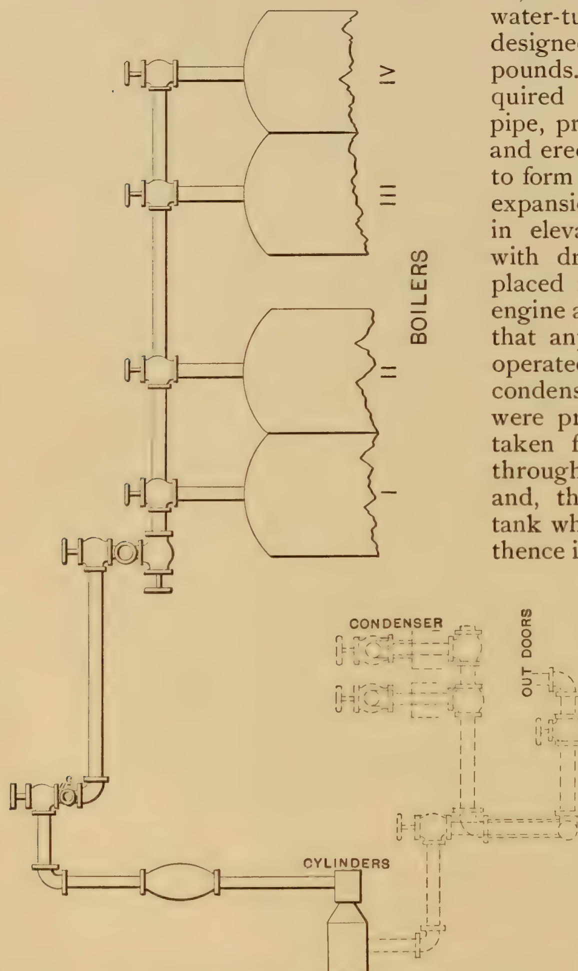


FIG. 7. ELEVATION OF THE SYSTEM OF PIPING AT CORTLAND.

Subsequent complications which arose in respect to a contract for the entire construction and to the supply of capital, led to a substitution of tubular for water-tube boilers. The boilers were designed for a working pressure of 175 pounds. The steam piping was required to be of the best lap-welded pipe, provided with extra heavy fittings and erected with elbows arranged so as to form swinging joints so as to take up expansion. The construction is shown in elevation in Fig. 7. A separator, with drips connected to a trap, was placed in the steam pipe line for each engine and the engines were arranged so that any one, or all, of them could be operated, as required. Two independent condensers of the Worthington pattern were provided. The feed water was taken from the hot well and passed through an economiser in the stack, and, thence, into a purifier or settling tank which was provided with a filter; thence it passed to the boiler. Two feed pumps were required; also two injectors, to be used for emergency feed.

The general arrangement adopted for the machinery is shown in the plan, Fig. 8, from which it is seen that the power house was an isolated building consisting of three rooms, namely an engine-room, 80 x 50 feet; a pump room, 12x40 feet; and a boiler room, 48 x 40 feet. The arrangements of the engines was such as to bring the main shafting in one line. The plan of the main steam pipe is shown by heavy lines; that of the exhaust, by dotted lines. The floor of the engine room is on an elevation of 3 feet above that of the boiler room, and 4 feet above that in the pump room. The water for condensing purposes was obtained from a well, which was connected with the river by a line of sewer pipe. The discharge from the hot well was emptied by a drain into the river.

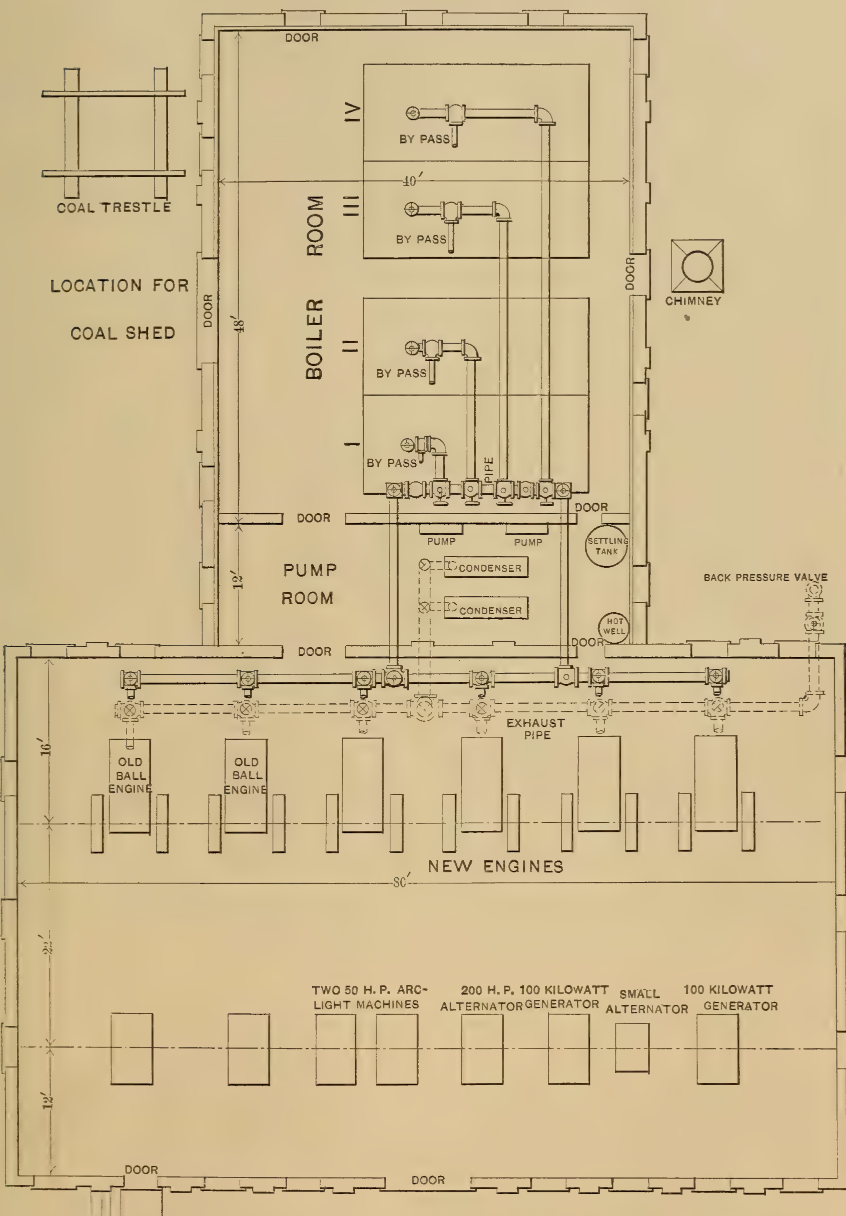
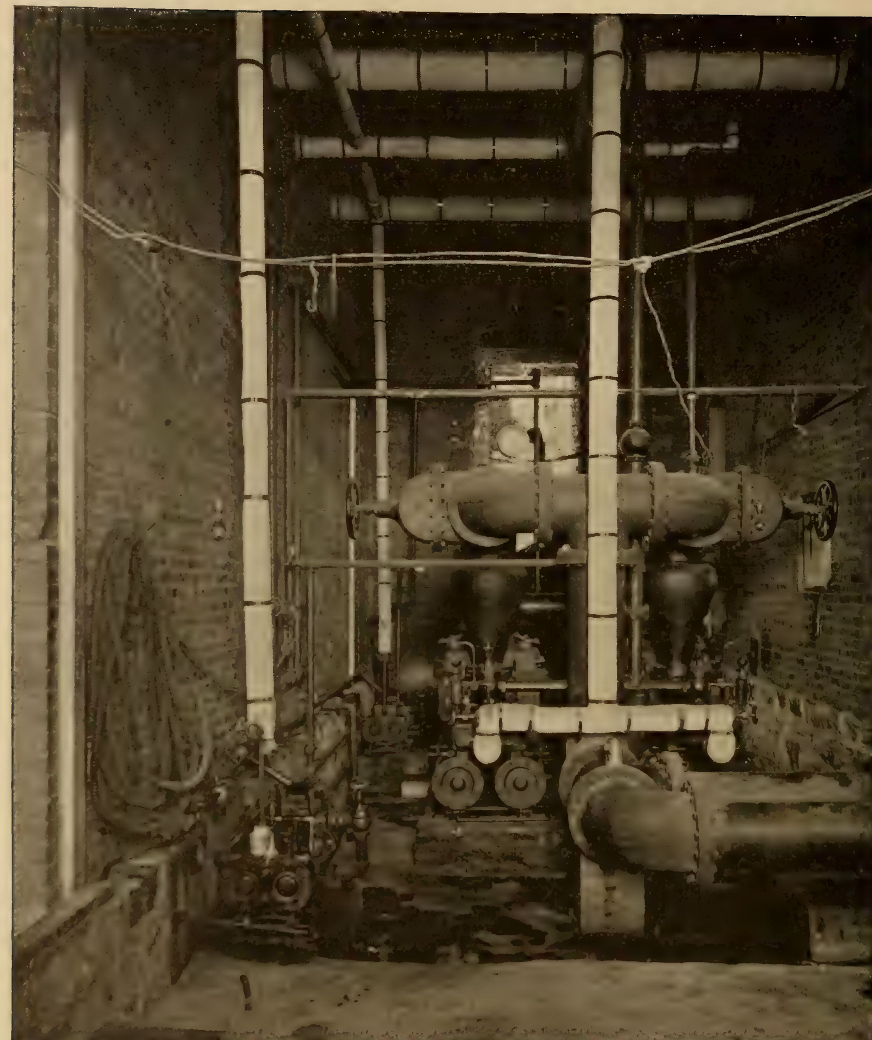


FIG. 8. PLAN OF THE POWER STATION OF THE CORTLAND HOMER TRACTION CO.



THE PUMPS AND CONDENSER.

The boiler plant consisted of four boilers, arranged in two batteries, provided with McClave grates and an automatic damper regulator. The discharge gases were taken from the front of the boilers to a horizontal pipe of large cross-section, which was above and between the boilers, and in which were placed 2000 feet of wrought iron pipe through which the feed water was pumped.

The building itself was designed without much reference to architectural effect. It was constructed of brick and stone in a substantial manner ; the roof was supported by heavy iron trusses and was covered with slate. The entire cost of the building and trestle for the coal cars was less than $7000 (£1,400).

The engines finally adopted, were of the tandem automatic type, with the low pressure cylinder outside the high, and arranged in such a manner that both pistons could be drawn out without taking down either cylinder.

The plant, although not fully com-

pleted, was partly put in operation on January 15, 1895. It was fully completed about June 1, so far as the power plant is concerned, but at the present time there remains some work to be done before the lighting capacity will be fully required. During the first few months, when a portion of the plant was operated and a part was still under construction, there was an excessive use of fuel which never has been fully accounted for. It is, however, partly accounted for by various circumstances and conditions, among which may be mentioned, first, the use of a simple non-condensing engine which was installed by the builders and operated while constructing the other engines; second, uncovered steam pipes and an unfinished building, which caused large radiation losses; third, men who were unskilled operating of the plant; fourth, the running of new machinery.

Two complete tests of the plant have been made with the railroad only in operation. All tests are in substantial agreement with the general results of one made by Prof. George B. Preston, at the Cortland Homer Traction Railway Power Plant from 5 A. M. to 5 P. M., on August 16, 1895. Steam for the engine operating the railroad was obtained from boiler No. 1, which also supplied steam for the injector feeding boiler No. 3, and for Argana steam blowers under the grates in boilers Nos. 1 and 3. Boiler No. 3 was operated to supply steam for a jet condenser pump and two boiler feed pumps supplying boilers 1 and 3. The following are the general results of the test:—

BOILER TESTS.	Boiler No. 1.	Boiler No. 3
Feed water tempt. in hot well, degrees Fahr	89	89
After economiser, degrees Fahr	128	128
Boiler pressure, gauge reading, pounds	94.5	94.5
Temperature of flue, beyond economiser degrees Fahr	243	243
Quality of steam per cent	97.5	97.5
Wet coal per hour, pounds	233	100
Dry coal, per hour, "	221	95
Combustible, per hour, "	103	82
Feed water, per hour, "	2,062	858
Dry steam, per hour, "	7,998	830
Evaporation per pound of wet coal, pounds	8.58	
Evaporation per pound of dry coal, pounds	9.04	
Evaporation per pound of combustible, pounds	10.40	
Evaporation per pound of combustible, from and at 212, pounds	12.1	

Steam (removed by) separator per hour, pounds	60 lbs.
Steam calorimeter per hour, pounds	24
Steam pressure at engine, "	94 5
Vacuum at condenser, inches	25
Quality of steam at engine, per cent	97.5
Dry steam per hour used by engine, pounds	1,658
Dry steam per hour used by steam blowers, pounds	120
Dry steam per hour used by injectors, pounds	66
Dry steam per hour used by condensers and pumps, pounds	858 lbs
I. H. P	60.4
Electrical horse-power	48
Steam per I. H. P. per hour, engine only, pounds	27.4
Steam per I. H. P. per hour, whole plant, pounds	45.4
Steam per Electrical H. P. per hour for whole plant, pounds	56.0
Coal per Electrical H. P. per hour, whole plant, pounds	6.3
Coal per I. H. P. per hour	5.2
Coal per K. W. hour	8.3

A discussion of the results obtained shows that the average load was only 0.35 of the maximum and that if the engine gave as good results as per the diagram, Fig. 3, we should have had by this condition steam consumption of 28 pounds per indicated horse-power per hour, which is not essentially different from that given by the test. The amount of steam used for the pumps and for operating the condenser, makes a very large portion of the whole. In this case it is about 30 per cent. of the total steam consumption, so that the steam used per I. H. P., when this is taken into account is increased about 50 per cent. This large steam consumption of the pumps led the superintendent of the plant to think that better results might be obtained by operating the plant non-condensing. A week's trial, however, showed an increase in steam consumption of about 25 per cent.

The actual coal consumed per hour for the whole plant is 5.2 pounds per I. H. P., 6.3 pounds per electrical H. P., and 8.3 pounds per K. W. These results can certainly not be considered low from any standpoint; yet, if we compare them with the diagram given in Fig. 6, which gives the actual results obtained in a very much larger station, we see that the results which were obtained in this case, with a very small load, are fully 15 per cent better than those shown for the best load.

It is not unlikely that marked changes in some directions would have been

highly beneficial to the economic operation of the plant. The operation of the independent condensers involves the use of large quantities of steam, which, by a different arrangement of machinery, or by the adoption of different forms, might possibly have been obviated. These wastes would have been saved by the use of a single engine and a long jack shaft to which could have been connected belt-driven condensers and pumps. But in diminishing wastes in this direction, they would have been increased in other ways many times more.

In conclusion the writer would say that the opportunities for securing the highest economy in this class of plants is not good, and believing it would be of interest to consider some of the difficulties involved he has presented a study of a design of a plant which was constructed with a full knowledge of the difficulties to be met and which, at best, can be considered as only passably successful, so far as economy is concerned.

SAVING FUEL IN A LARGE OIL REFINERY.*

By Dr. Charles E. Emery.

ONE of the most interesting professional engagements during the past year has been the study of conditions obtaining in the large oil refinery of the Tidewater Oil Co., at Bayonne, N. J., with a view of recommending means to obtain a saving of fuel. An incredibly large amount of steam is required in such a place. It is used for power to operate the engines for the various manufacturing establishments, such as barrel, can, and box factories; to operate steam pumps to transfer the oil and finished products to different parts of the yards; to press out the paraffine or wax from the heavier oils; to operate hydraulic presses for higher pressures; to pump water in large quantities for cooling purposes, ammonia for refrigeration, etc. Some steam power is also required for electric lighting. A very large part of the steam supply is, however, required for various heating operations connected with refining.

In the refinery referred to there were 5500 horse-power of boilers, installed in four boiler houses in different parts of the grounds, which boilers were originally forced much beyond their capacity a great deal of the time. The coal consumption for steam purposes amounted to about 64,000 tons per year, independent of which a very large quantity was consumed directly under oil stills. The question of the saving of fuel had been agitated before the writer was consulted, and some savings made by separating the boilers for two different departments in the refinery, so that each could be held responsible for its own consumption. It had also been considered that there were some connections between the different boiler houses, which could be simplified, as it had been found necessary to keep all the boiler houses in operation nearly all the time.

The executive officers had also entertained a proposition from the prominent electric companies to erect a central electric plant for generating alternating current, it being proposed to substitute alternating motors for all of the steam engines in the establishment, of course putting in new pumps, adapted for operation in this way. The cost seemed so large that the writer was consulted as to the best method desirable under the circumstances.

It was found that the executive officers at the refinery had studied the

* A paper presented before the American Society of Mechanical Engineers.

problem very thoroughly, and that they knew in a general way the causes of the large consumption of steam. One of them had, some time before, sent to the writer for a copy of experiments which he had made on the cost of steam power with ordinary steam pumps, which led to an investigation of the cost of power with the large pumps of the refinery, the method generally adopted being to ascertain the weight of exhaust steam delivered through a temporarily arranged surface condenser, or, in some cases, the extra weight caused by exhausting directly into a vessel of water, the water used being compared directly with the theoretical power obtained from the gallons pumped and the pressure of delivery.

It was found that many of the steam pumps were using as high as 240 pounds of water per net horse-power per hour, and only in exceptional cases could one be found which could deliver a horse-power with as low as 80 pounds of feed-water. The general impression seemed to be that the steam pumps were requiring, on the average, 150 pounds of water per horse-power per hour. The advantages of using exhaust steam were also appreciated to a certain extent, as exhaust steam pipes were being erected and connected so as to keep the various stills and tanks warm during the winter.

The preliminary report of the writer, which was not based on full knowledge of all that had been done before, corroborated the opinions of the officers as to the causes of the large consumption of steam, but considerably modified the suggestions as to the methods of reducing the same. The large electric plant was not approved. A smaller electric transmission was recommended to reach various outlying points where steam had to be transmitted a long distance at very great expense in condensation, independent of the power developed, since it was necessary in winter, and desirable in summer, to keep the pipes warm all the time, although the power was at many of the points used only occasionally.

An extension of the exhaust system was recommended even if it became necessary to increase the back pressure, and it was recommended that a number of power stations be established in which would be erected good high-pressure non-condensing engines operating power pumps to take the place of the numerous steam pumps in different parts of the works, the exhaust from such engines to enter the exhaust mains and to be used for heating purposes. It was pointed out as desirable that the changes be made somewhat slowly, so that experience gained at one plant could be applied at another, and so that the class of engine best adapted for the purpose could be determined. Evidently, if all the exhaust would eventually be required a cheap form of engine could be used, and, if the contrary was the case, good compound condensing engines could be used at some of the locations.

The suggestions were adopted, and considerable work has been done under the immediate direction of the executive officers in consultation with the writer. At the present time the system of local plants operated by high-pressure steam engines and power pumps has been applied at two points in neighbourhoods where the least exhaust steam is required, and the exhaust steam from nearly all the engines and the large number of wasteful pumps has been collected and used at a pressure of about 10 pounds in the steam stills, the results showing that nearly all of it could be utilised.

The result of the work thus far accomplished has been to reduce the coal consumption for steam purposes fully one-half, or about 32,000 tons per year. The saving has gradually increased from the time the work was commenced, and has been 54 per cent., compared with the previous year, for the last three months, though the entire work laid out is not yet complete. One of the four boiler houses has been closed, and experiments are in progress to ascertain how many more boilers can be shut down without forcing the remainder above the economical limit.

The principal part of the saving has been due to the use of exhaust steam. Its application in steam stills required experiment, so the results could not have been accomplished without the hearty co-operation of the executive officers of the establishment. Before the changes the yards were overhung by clouds of escaping steam ; now hardly any is visible. In comparison, it seems like Sunday, or as if the work were stopped, whereas, actually the output is, at times, greater than before. The fact that so much exhaust steam could be utilised has somewhat modified the original plans of dispensing with all the steam pumps. At points where there is little condensation due to exposure, evidently the lack of efficiency is of minor importance, as the heat passes on and is utilised for heating purposes. In outlying districts, however, there was a large amount of condensation in pipes and pumps, necessarily located out in the air in many cases, to avoid danger from fire. A number of these pumps have been housed so as to save loss by condensation, and power pumps will be substituted for others in another sub-station, thus reducing the surplus of exhaust steam, when improvements will be stopped for a time until experience indicates the desirability of further change.

The question may be asked why it was decided to give up the electric-power system. The principal reason was that it was quite expensive, and, moreover, not warranted by a balance of the advantages for a location where much of the exhaust steam could be used for heating purposes. Even if interest on first cost were neglected, the quantity of exhaust steam which could be utilised for heating purposes would be many times as much as the steam required to operate the dynamos. This last steam had to be supplied as well as the first, and, if supplied through steam engines, the power could be developed with only the extra cost due to heat lost in the performance of work, which is comparatively trifling in such a place, and the heat lost by radiation during transmission. So long as the heat lost by radiation was less than the cost of the power in the best compound engines, the use of the latter was not warranted even on economical considerations, and when the cost of the electric plant was considered, the balance was decidedly in favour of the plant finally decided upon. It does not follow that this decision would apply as a general rule. Every case must be decided on its own merits, but in making such decision great pains must be taken to obtain the probable results in practice rather than those which have been shown under experimental conditions.

The small electric transmission plant previously referred to is now in operation. It is a three-phase alternating system, put in by the General Electric Company. A 75 kilowatt, 550 volt generator is provided, it having been decided, on consultation, to make it large enough to furnish all the incandescent lights then supplied from three small plants in different parts of the yard. There are about 60 horse-power of motors distributed at outlying points, the units varying from 5 to 30 horse-power. The electric conductors displace about 2000 feet of steam pipe of various sizes, which it was necessary to keep hot winter and summer. In locations where gases exist that a spark would light, the variable starting resistance has been omitted from the motors, and the switch-blades are immersed in oil, so that the electric apparatus is absolutely sparkless. The change has improved the electric lighting, and the motors are also operating quite satisfactorily.

CROSS-COUNTRY POWER.

LONG-DISTANCE TRANSMISSION OF POWER BY ELECTRICITY IN THE UNITED STATES.

By John McGhie.

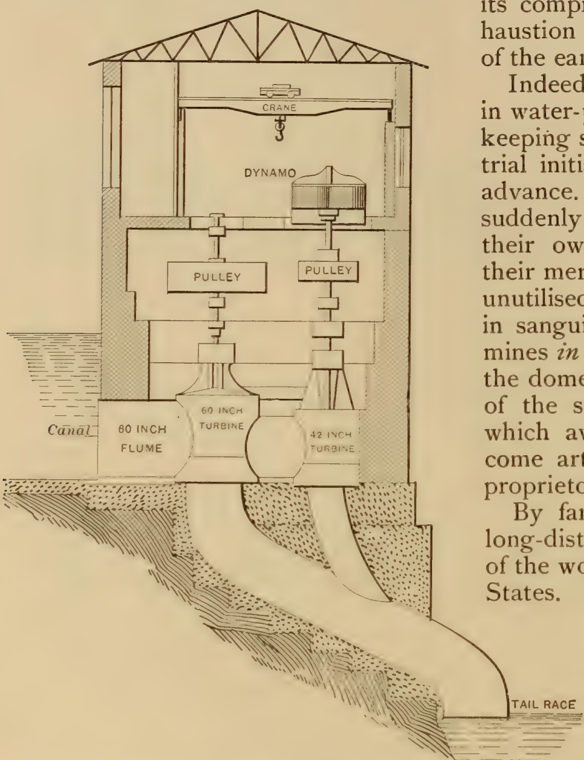
THE branch of applied electric science which has recently received the largest share of the attention both of theoretical and working electricians is, without doubt, that occupied with the transmission of power over distances, more or less great, from its source of least expensive generation, and the most economical method of useful dissemination after its arrival at the central point of distribution.

Previous to a date which may be fixed early in 1891, the electric mind had been almost exclusively occupied over problems relating to improvement in the method of applying the electric current to arc and incandescent illumination, or to the service of surface transportation, and but little attention had been given, from the commercial point of view at least, to the important question of the long-distance transmission of energy.

With the comparative perfection of the arc and incandescent lamp, the direct-current stationary and railway motors, and the various systems of electrical generation and alimentation, however, came the desire to enter a new field of promising aspect. For the theoretical electrician that of long distance power transmission offered a fascinating invitation ; to the manufacturers of electrical apparatus, it looked an arable land which, with but slight tilling, might laugh in a bountiful harvest of acceptable profits. The former turned toward the solution of the various problems with the eager expectation of new discovery ; the latter, with the less elevated idea of large gain. The principal cities in the United States were already fully equipped both from the illumination and transit points of view, and the promotion of companies and the sales of huge current supply plants with the extensive profit on each became less and less numerous. The electrical business was slowly coming down to a strictly commercial basis, necessitating constant labour and extensive facilities to allow of even a small profit. The era of electrical employ for the operation of

the steam road had not yet dawned, but the commercial sky was pink with the hope of successful results in the long-distance power transmission field.

The feasibility of power transmission by means of electricity over distances of limited extent had been clearly demonstrated in the long years of experience with the direct current, but transmission by means of the direct current speedily reached a limit beyond which, for economical reasons, it became inadvisable to go. Yet, it was conceded possible that power could be transmitted over very long distances. How best to effect this became the urgent question of the hour.



CROSS SECTION OF THE NEW PORTLAND POWER STATION.

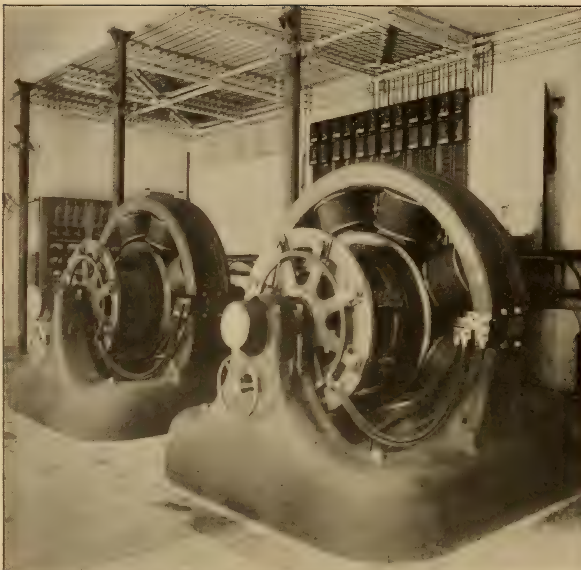
The direct current was, perforce, discarded and the alternating current called into requisition. Attainment of an economical solution was by no means easy. Difficulty after difficulty arose, requiring countless experiments to elucidate; and alteration after alteration in machinery was made, involving the expenditure of vast sums. By successive and painful stages a solution was finally reached, and to-day the long-distance transmission of power by electricity is an established economic fact of a potentiality which seems limited in its comprehensiveness only by the exhaustion of the available natural forces of the earth.

Indeed, everything points to a corner in water-powers, speculative enterprise keeping steady step with honest industrial initiative, and generally a little in advance. Waterfall and cataract have suddenly assumed a greater interest to their owners, than that imparted by their merely scenic features. Hitherto unutilised water powers have become, in sanguine imagination, possible gold mines *in futuro*, and the elimination of the domestic coal heap and relegation of the steam engine to the oblivion which awaits the discarded, have become articles of faith with water power proprietors.

By far the greatest number of the long-distance transmission installations of the world, are situated in the United States. The American seems endowed with the courage of temerity, and is willing to adopt a new thing with promise only, where other nationalities demand assurance or proof. A possibility has a special attraction for the American mind, and the risk of its realisation is willingly run. It is this spirit that has covered the United States with electric lighting stations, spread a network of electric car lines over every city of any importance in its boundaries, and initiated the supersession of the steam locomotive itself from its main line railways.

The first long-distance power transmission plant perhaps on the American continent, was that installed by the old Thomson-Houston Company in 1887 in Guatemala, where two 1500-light alternators transmitted power for lighting purposes 3¾ miles to the city. The second section of this plant consisted of arc-lighting machines, located 7½

INTERIOR OF THE NEW POWER STATION AT PORTLAND OREGON,



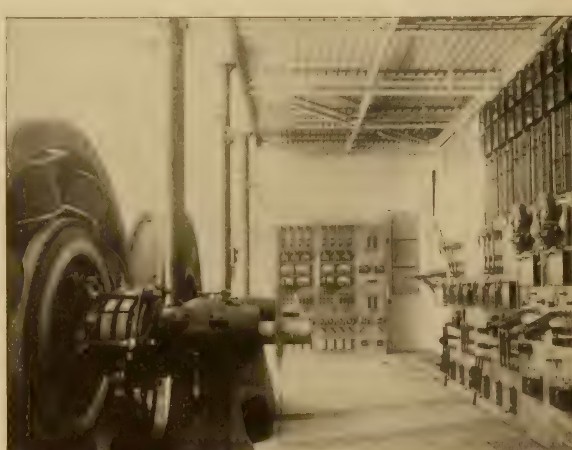
ROTARY CONVERTERS AT PORTLAND. THE DIRECT CURRENT SIDE.

miles from the city. Another early successful transmission plant and an excellent example of direct-current transmission is that installed for the Caroline Mining Company at the Virginius mines, near the summit of Mt. Sneffles, near Ouray, Colorado.

Up to the time electricity was brought to these mines, they were operated by steam power, and the necessary coal was carried to the furnaces on the backs of burros, up one of the stiffest zigzag trails in Colorado. Including lost coal and extinguished burros, the cost of the fuel at the furnace door was about $18.00 per ton (£3 12 sh.)—the annual cost $40,000 (£8000),—a sufficient incentive to revolutionary methods. The source of energy now, is the waters of the Red Canon creek, brought down to two Pelton wheels of 500 H. P. and 720 H. P. capacity respectively, through a pipe line, 4000 feet in length, running along the rocky side of the canon. The head obtained is 485 feet.

The Pelton wheels were belted to one 100 K. W. and one 60 H. P. Edison bi-polar generator, now replaced by one 200 K. W. multipolar generator, furnishing direct current at 800 volts. The direct-current was employed, none other being then available. The alternating current motor was not yet commercially practical. The current is carried from the power house for a distance of 19,000 feet up the mountain to the mine, 12,700 feet above sea level, and about 5000 above the snow line. It is used to drive motors operating pumps, blowers and stamp mills.

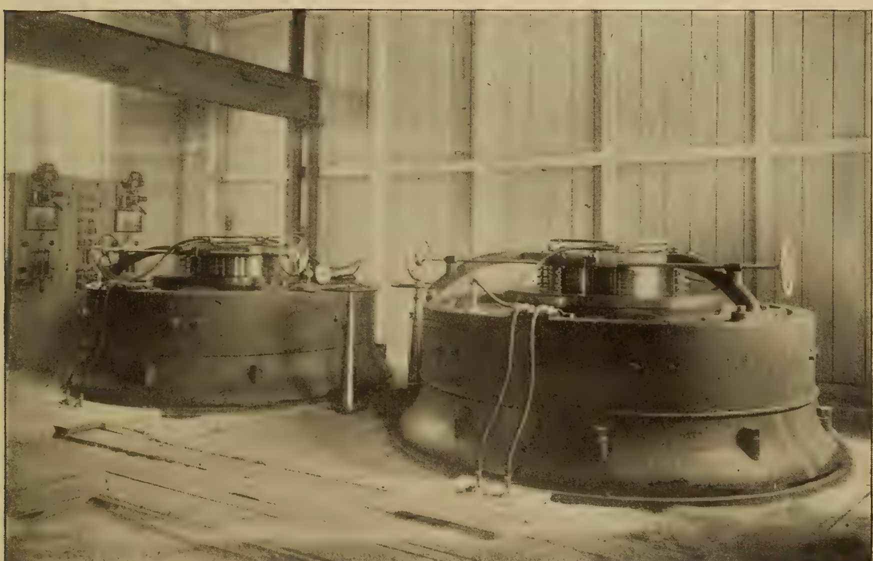
The installation offered almost every difficulty possible in the erection of a transmission plant. The pipe line is laid along the side of a rocky canon; the lower part of the wire line is brought through dense timber, and the upper part extends over a rocky plateau above timber line, where the snow is frequently 20 feet deep on the level, and lightning storms are violent and



THE ALTERNATING CURRENT SIDE.

persistent. The operation of this plant has proved successful and the employment of electricity has enabled the company to work low-grade mines in the same group, which, previous to its adoption, could not be operated on account of the meagre results obtainable with the apparatus then at command. A somewhat similar installation was made in 1888 at Aspen, Colorado, when Edison and Sprague apparatus was used.

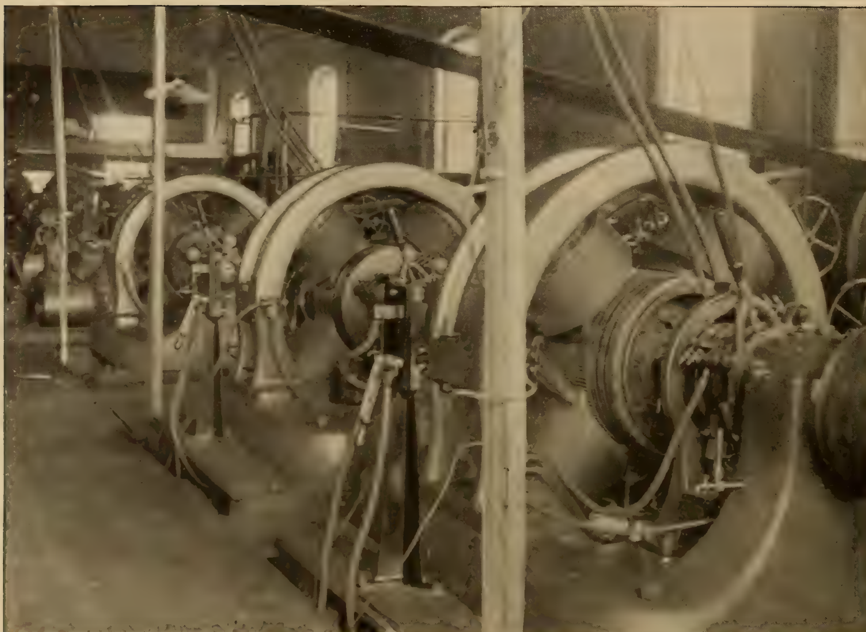
Another early plant was installed in the Northwest for the purpose of transmitting current for purely lighting purposes, from Oregon City to Portland, Ore., a distance of nearly twelve miles. The current was straight alternating, delivered to the transmission wires at a pressure of 4000 volts, and received at the sub-station at Portland at 3300 volts, there reduced, in transformers, to 1100 volts and again, by subsidiary transformers, to 100 and 50 volts for distribution. The generators were of special construction to meet the conditions involved in the delivery of so high a pressure as 4000 volts direct from the brushes, and involved many new features of interest.



THE EXCITERS IN THE PORTLAND STATION.

At Telluride, Col., climatic conditions, similar to those met with at Ouray, were encountered. In this case electricity is transmitted for purely power purposes and is used at the Gold King mill for the operation of crushers and stamps. Fuel could be delivered at the mill only at enormous cost, and the power of a water fall, three miles distant, had been running to waste for all time previous. Coal was, therefore, abandoned and the water power laid under tribute.

The water under a head of 320 feet is brought to a Pelton wheel, driving an alternating current generator, compounded to maintain a constant pressure of 3000 volts at the motor. The current is carried over a line of bare wire to the mill, three miles distant, and operates a synchronous, alternating-current motor of 100 horse-power, brought up to the necessary speed by a small motor of modified multiphase type, and then, excited, running as a self-acting alternating current dynamo. This small motor is always in requisition, bringing the larger up to speed whenever it falls out of step with the main generator.



THREE-PHASE GENERATORS IN THE MAIN STATION AT LOWELL, MASS.

The line passes over a rugged country exposed to snow and lightning storms, the snow occasionally almost covering the poles. This installation will shortly be increased by the addition of four 800 H. P. two-phase generators; two for installation at Telluride and two at Provo.

The noteworthy installation at Bodie, California, in which a system, similar to that followed at Telluride, is employed, was fully described in CASSIER'S MAGAZINE for March, 1895. Single-phase current, generated by a 120 Kilowatt Westinghouse machine at 3400 volts, is transmitted 12.46 miles to a 120-horse-power synchronous motor, driving stamps and other miscellaneous mining mill machinery. The motor is brought up to speed by a 10 horse-power Tesla motor and then runs in step with the main generator. The daily economy effected by electricity in this plant, where the annual coal bill amounted to \$25,000 (£5000) yearly, is from \$35.00 to \$40.00 (£7 to £8).

Up to this point long-distance power transmission had not really emerged from the region of experiment; the commercially practical had not been reached, and advance seemed, for the moment, checked. Prof. Ferraris in Italy had been preaching new methods and Mr. C. E. L. Brown, of the Oerlikon works in Switzerland, Herr Dobrowolsky, of Berlin, Prof. Cabanellas, of Paris, and Mr. Steinmetz, Mr. Tesla and many others in America had followed them up with experiment and attained many predicted and some unexpected results.

The multiphase alternating system of electrical generation, a variation from the hitherto accepted teachings, was brought into the electrical field, and an immense and immediate impetus was given to the work. The high-voltage alternating current was recognised as the only economical means of transmitting power over very long distances, and its feasibility was conclusively demonstrated in Germany in 1891 by an experiment which has become classic in long-distance transmission annals.

By the combined efforts of Messrs. Brown and Dobrowolsky, 300 horse-

power, generated from a water fall at Lauffen, was carried, at 25,000 volts, over bare wire to Frankfort, over 100 miles distant, and was there transformed and utilised to drive exhibition motors This decided the question of possibility, and long-distance transmission work became at once an important consideration with electrical manufacturing companies in the United States, the keenness of their competition speedily bringing the necessary apparatus within industrial reach.

In perhaps the first high-voltage, long-distance transmission plant installed in the United States, however, the single-phase alternating current was still adhered to. This plant was erected at San Antonio, California, to transmit to Pomona the power furnished by the waters of the San Antonio river, which are drawn through a canal, 1320 feet long, and a length of steel pipe of 2000 feet, led down the mountain slope to the power house, there to give 1900 horse-power from a head of 390 feet.

The electrical plant consisted of one 120 K. W. single-phase generator to which has since been added another unit of similar capacity. The current, generated at 1000 volts, is raised in transformers to 10,000 volts and is carried on bare wires 13¾ miles to Pomona, and 28¾ miles to San Bernardino. It is delivered at 9500 volts to the former town and at about 9000 to the latter, and is reduced at the substations to 1000 volts before being distributed to the individual converters. It is said that the two lines were once connected in series, making a continuous circuit of over 85 miles, and 100 H. P. were transmitted successfully. Information regarding the efficiency obtained has, however, not been forthcoming.

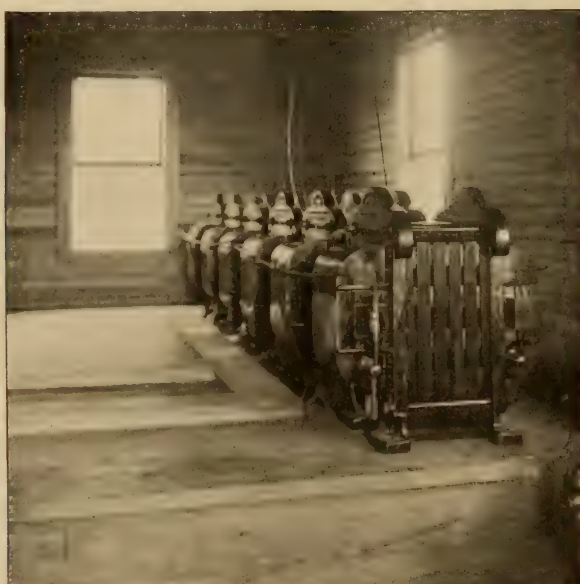
From this point, multiphase alternating systems displaced others for long-distance work. The General Electric Company developed the three-phase system, and all the three-phase plants in operation in the United States have been installed by it. The company also improved the single-phase system so that it could as readily be used for motor as for lighting purposes. The Westinghouse Company and the Stanley Company, on the other hand, developed the two-phase system, and have installed most of the plants operating under this method. The two-phase system is that used at Niagara, N. Y., Telluride, Colo., Anderson, S. C., Washington, Mo., and four or five other places, while the three-phase and monocyclic' systems are securing a widespread adoption in other places all over the country.

The first three-phase plant in America was installed in the summer of 1893 for the operation of the machinery in the electric station at Hartford, Conn. The power is taken from the Farmington river, where a head of twenty feet is obtainable, to drive a 300-kilowatt three-phase low voltage generator, the current from which is raised to 7000 volts and transmitted eleven miles to Hartford. It is used to drive a 300-Kilowatt three-phase alternator acting as a synchronous motor, which, in turn, drives arc and incandescent lighting machines and street railway generators.

THE SUBSTATION AT EAYR'S MILLS, NEAR LOWELL, MASS., U.S.A.

The second three-phase plant started was at Redlands, California, in September, 1893, where the water of Mill Creek Canon is utilised. The water passed, first, through a 160-foot tunnel and then through 7250 feet of steel pipe, giving a head of 353 feet at the two double-nozzle Pelton wheels, which drive 250 kilowatt three-phase machines, delivering current to the transmission lines at 2500 volts. The water, after use, is led into a ditch, and employed for irrigation purposes. The current is transmitted partly to Redlands, 7½ miles distant, where it is distributed for lighting purposes, and partly to Mentone, 4½ miles distant, where it drives a 150 kilowatt three-phase synchronous motor, operating ice machines 24 hours a day for 365 days in the year.

One year after the plant was started, 175 horse-power in induction motors and 2000 incandescent lights were running in Redlands, light and power being used from the same circuit without affecting the lighting service. The question of unbalancing was also settled, no difficulty being experienced in balancing the loads on the three legs, the load difference neither affecting the lights nor the generators.



STEP-DOWN TRANSFORMERS AT LOWELL.

At Taftville, Conn., three-phase current, generated at Baltic, is employed to drive a motor in a large cotton manufacturing plant. Water power in this case is transmitted 4½ miles. The generating plant consists of two 250 kilowatt three-phase generators, the motor plant, of two 250 kilowatt synchronous motors, which replace two discarded 350 H. P. Corliss engines, and drive not only all the machinery in the mill,—1700 looms,—but also the three 80 H. P. direct-current railway generators furnishing current to the Norwich Street Railway system. No auxiliary motor is required to bring the main motors up to the speed ; they are self-starting. The efficiency of the plant is set down as 80 per cent.

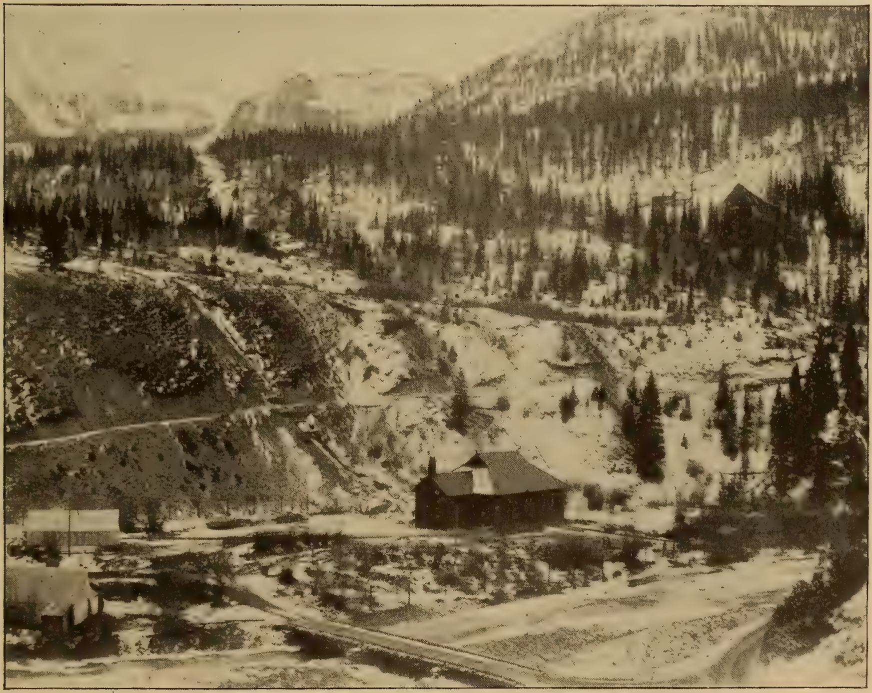
At Concord, N. H., is a transmission plant of almost similar length. A water fall at Sewall's Falls, on the Merrimac river, is utilised in part to drive two three-phase 250 kilowatt

generators which early last year furnished current for not less than 400 horse-power in motors, 6000 incandescent lamps, many arc lamps and a large heating load. The transmission pressure is 2500 volts, reduced to 110 on the secondary wires. Current, similarly generated and similarly employed, is also transmitted a similar distance from a water fall on the Boardman river to Traverse City in Michigan.

The three-phase transmission at Columbia, S. C., while it involves no question of distance, is yet of great interest from the fact that it emphasises the advantages inseparable from the multiphase electrical systems in mill operation. An exhaustive description of this plant, from the pen of Dr. Louis Bell, appeared in the issue of this magazine of February, last year.

The foregoing plants, with the exception of the last, may be considered as the pioneers in the field of long-distance transmission by multiphase currents in the United States. During their construction, contracts had been made for others, involving a conception and execution startling in their boldness. Niagara was to be laid under contribution, the old transmission plant at Portland, Ore., had become inadequate, and in California many magnificent water falls were urgently demanding employ. The readers of this magazine are familiar with the Niagara electrical plant, since it was described in these pages with a wealth of detail and illustration, fully befitting the importance of the enterprise.

In the first part of this article the old Willamette Falls plant was mentioned. Side by side with this, has been erected the first part of a three-phase plant which will be the most important in the Northwest. In this undertaking, interesting questions in electric and hydraulic practice came up and to these the plant is to-day a complete answer. The Willamette Falls, about 12 miles above Portland, Ore., have a capacity of about 50,000 horse-power at a head



THE SILVER LAKE MINES POWER STATION AT SILVERTON COL., U. S. A.

of 40 feet; of this, 12,800 horse-power will ultimately be taken and utilised in a station, of which five of the twenty sections are already built. It is divided into two stories, the lower containing the hydraulic plant, and the upper the dynamos, directly connected to the shafts of huge Victor turbines below.

Each three-phase generator is of special design, the armature revolving yet delivered from any generator in America. At this pressure the current passes to the line and is transmitted to Portland, where it is reduced in transformers to 400 volts, and delivered to rotary converters, each of 400 K. W. capacity, which convert the alternating three-phase current into direct current of 550 volts pressure for street railway and stationary motor service.

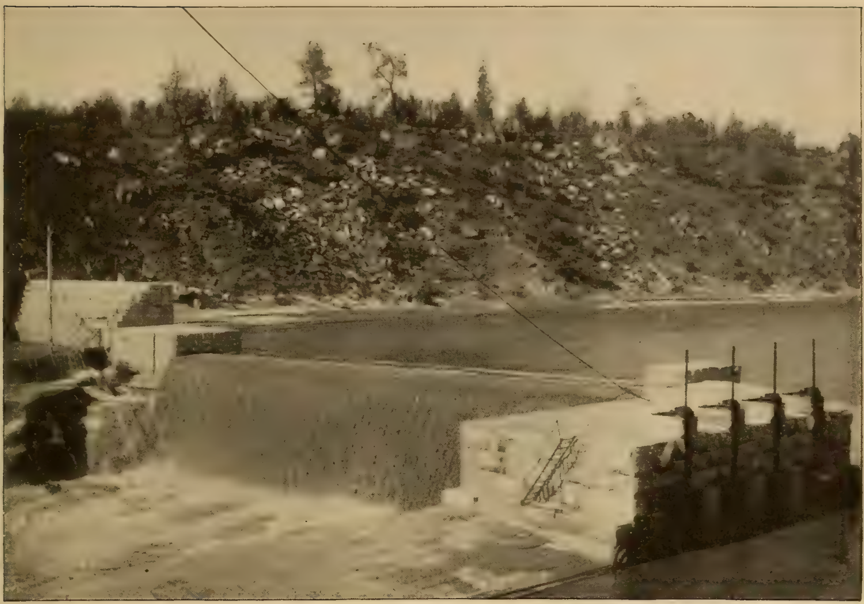
THE POWER CANAL AT FOLSOM, CAL., LOOKING TOWARD THE POWER HOUSE.

in a horizontal plane, and three, of 450 kilowatts capacity, are in place. Twenty of these machines will complete the plant. The peculiar feature of this plant is the employment of large quantities of the power for street railway service, involving the transformation of the polyphase current into direct current for railway service. This necessitated the selection of a frequency of 33 cycles and the use of rotary converters.

The potential of the generated current is 6000 volts,—the highest pressure

Telephone, arc light, straight alternating and three-phase current wires are all strung on the same poles without interruption of any kind in the different circuits. At Portland the distribution of light from the secondaries is effected on the four-wire system at 133 volts between any two wires. New stationary motors will not be operated from the direct current lines, but will be of the induction type connected directly to the three-phase, 400-volt circuits.

The three-phase plant at Portland,



THE DAM AT FOLSOM.

Ore., and that at Lowell, Mass., are the first plants in the world, in which three-phase alternating current is converted into direct current for railway service. At Lowell, the current is generated from three 120-kilowatt generators at 360 volts and passes to air blast transformers which raise it to 5500 volts. It is then carried along the highway on the same poles which carry the direct railway current feeders, as far as the substation at Eayr's Mills, about six miles from Lowell; there part of it is transformed down to the original pressure of 360 volts and carried to rotary converters from which it issues as direct railway current of 500 volts. The balance of the high-voltage current continues on to Nashua, N. H., about fifteen miles from Lowell, where it undergoes a similar transformation and conversion. The direct current obtained from both substations is used to operate the interurban railway system which extends from Lowell to Nashua,—a distance of about 15 miles. Part of the current from the Nashua

ANOTHER VIEW OF THE FOLSOM DAM AND HEADWORKS.

THE CALIFORNIA STATE POWER-HOUSE AT FOLSOM. FLOW OF WATER, 85,000 CUBIC FEET PER MINUTE ; FALL, 7 FEET 4 INCHES. 1,000 H. P.

substation operates the railway lines ot that town.

The Far West has a plant of considerable importance at Folsom, where power is generated from the difference in level of the American river, and is transmitted to Sacramento, over 21 miles away. In many particulars this installation may be considered unique. A dam containing 37,000 cubic yards of masonry has been thrown across the American river, the waters of which are then brought through a canal of solid masonry, 9500 feet long, and about 50 feet wide. The right bank of the second and third sections carries a broad gauge railroad track.

The hydraulic portion of the transmission plant consists of four pairs of 30-inch McCormick turbines of 1260 horse-power each, operating under a head of 55 feet, having the shafts directly connected to the armature shafts of the four dynamos. These machines are three-phase generators of 750 kilowatts each, delivering current at 60 cycles and 800 volts, to air blast transformers, each of which has a capacity of 265 kilowatts, three transformers being fed by each generator. From the transformers the current issues to the line at a pressure of 11,000 volts.

The pole line is double throughout, has a total length of about 21½ miles, and is carried on large double-petticoat porcelain insulators, tested to 25,000 volts alternating. On the same poles a telephone line is carried without interference from the tremendous current passing in its vicinity. At the substation in Sacramento the pressure is reduced, in transformers, from 10,000 volts to 125, 250, 500, 1000 and 2000 volts, as may be required.

At present, three 250-K. W., 500-volt, three-phase synchronous motors are working, driving the Sacramento Street Railway plant, and three large 100-arc light Brush dynamos. The balance of the current is reduced to 125 volts and distributed over Sacramento on a modified three-phase system for incandescent lighting and induction motor service.

Two three-phase mining plants deserve notice. They are those at Silverton, Colo., and at Park City, Utah. That at Silverton is the first three-phase plant installed in the Rocky Mountain regions. It utilises a water power taken from the Animas river through a three by four-foot flume, 9750 feet long. The electrical installation consists of two 150-kilowatt generators, driven by two

double-nozzle Pelton wheels. The current, at 2500 volts, is transmitted back up the mountains, a distance of over three miles, to an altitude of 12,300 feet above sea level, where it is used to operate various mining machinery in the Silver Lake Group of mines and to drive the stamps and crushers in the mill. Previous to the installation of this electrical plant the mines were operated by steam, and the coal cost $8.75 (£1 15s.) a ton at the mine. It is calculated that an economy of $36,000 (£7200) a year will be effected by the use of electricity.

The Ontario mine is located near Park City, in Utah, and the power is derived from the water of the drain tunnel of the mine,—the most expensive tunnel ever constructed by any mining company. It is three miles long and discharges 1000 cubic feet of water per minute from its mouth. This water, under a head of 120 feet, drives generators of the General Electric monocyclic type, which furnish current at 2500 volts for transmission around the mountain to the Ontario and Daly mines, five and a half miles distant, where it drives the mills and lights the surrounding buildings. Current from these machines is also taken to light the neighbouring town of Park City.

Utah will shortly have another transmission plant, similar in its scope to that at Sacramento, California. The waters of the Big Cottonwood Canon are to be utilised to generate current for use at Salt Lake City, 14 miles away. At the power station a head of 380 feet will be obtained to drive four double Pelton wheels, each connected to a 450-kilowatt three-phase generator. Six air blast transformers, of 265 K. W. capacity each, will raise the voltage to 10,000 volts for transmission, and nine of 175 K. W. capacity will reduce it to 2000 volts, for distribution to the local transformers and converters. As soon as the transmission is completed, the present steam plant of the electric light company will be discarded and the entire lighting and distribution system will be unified, while a powerful incen-

THE TAIL RACE SIDE OF THE PORTLAND POWER HOUSE.

tive will be provided for the development of the many mining and manufacturing industries of which Salt Lake City is the centre.

A two-phase plant at Anderson, in South Carolina, has recently been started. It utilises a small water power on Rocky river, six miles south of that city, capable of yielding 200 horse-power with the present machinery, consisting of a 24-inch McCormick turbine, and a belt-driven Stanley two-phase alternator of 150 kilowatt capacity. Current at 5500 volts is delivered to the line, without the intermediation of transformers, and is transmitted over four bare copper wires to the substation at Anderson, where it is reduced in transformers to 1040 volts and distributed over the city. It is used to operate incandescent lamps, arc lamps and motors, one of 30 H. P. driving a large duplex pump. The line loss is extremely small,—not more than 3½ per cent. This plant is to be followed by another of similar type to transmit power five miles to Elberton, Ga.

We have now reached a point where 4000 horse-power is successfully transmitted by multiphase current over a distance in excess of twenty miles. California will shortly have a transmission plant which will transmit power over nearly double that distance, the power being carried over thirty-five miles to Fresno from the North Fork of the San Joaquin river. This stream runs for several miles down a rocky canon, forming many cataracts and rapids. At the head of the rapids a canal will take the water along the summit of a high ridge, which will be followed for a distance of six miles to a point nearly 1500 feet above the San Joaquin, where the canal will terminate in a reservoir, 8 acres in extent and ten feet deep.

Four thousand feet of pipe-line will run down from the reservoir and give a minimum of 7000 H. P. at the extraordinary head of 1410 feet. This will mean a pressure at the bottom of 600 lbs. The three wheels will be single-nozzle Pelton wheels, each driving a 340-kilowatt three-phase generator, delivering the current to the lines at 11,000 volts through transformers for transmission 35 miles to Fresno, where it will be transformed down, as at Sacramento, and distributed to the inhabi-

LOOKING UP THE CANAL FROM THE FOLSOM POWER HOUSE.

THE DAM AND FLUME FOR THE POWER STATION FOR THE VIRGINIUS MINE IN COLORADO.

tants for every conceivable lighting and power purpose. This transmission will be the longest ever commercially attempted up to the present time.

The majority of the foregoing enterprises are occupied with the transmission of power for general lighting and power purposes. Owners of individual textile mills, powder mills and factories of all kinds are also busily debating the advisability of adopting the new power. The Columbia Mills installation is a case in point, and additional emphasis is laid by the plant just started at Pelzer, S. C., where important cotton mills will be operated by electricity generated from three 750-kilowatt three-phase generators, running three miles distant. No raising transformers will be used, but the current at 3300 volts will go direct to the transmission wires. One mill will have a 400 H. P. synchronous

motor receiving current from the high-voltage lines ; another will have more than twenty induction motors, ranging from 110 horse-power down to 5 horse-power, for which, and for 1200 incandescent lamps in the mills, the current will be reduced in transformers.

Electrical transmission over long distances has up to the present time taken the power from different waterways ; no attempt, however, has yet been made to utilise the immense heaps of low-grade fuel lying unused at various points Mr. Thwaite in England has enunciated a proposition to transmit power from the midland collieries to London, and the culm piles of Pennsylvania promise large returns to the man bold enough to undertake the utilisation for a supply of cheap power to neighbouring cities.

Much might easily be written of the widespread and beneficent effects which the development of economical systems of power transmission will bring about, but they lie outside the scope of this article and received attention at competent hands in the opening issue of Cassier's Magazine for 1896. Suffice it to say, that we are only on the edge of a new era—one in which innumerable benefits will assuredly come, almost unbidden, to the busy workers of the world, by the harnessing of the great unused forces which nature has so bountifully provided.

WATER POWER.*

By Samuel Webber.

THE storage of water supply, and the cost of its development and maintenance, seem to belong more particularly to the civil than to the mechanical branch of the engineering profession ; but as the utilisation is mechanical, and the whole matter is intimately connected, it seems proper to offer a few general notes on the subject of the supply of water necessary for its mechanical utilisation.

The engineers, who have been for many years engaged in the question of water supply for large cities, have laid it down as an established fact that by means of proper and complete storage basins one-half the annual rainfall may be saved, the other half being either absorbed by vegetation or dissipated by evaporation.

* From a paper presented to the American Society of Mechanical Engineers.

This amount has been annually estimated for our northern cities as 1,000,000 gallons per day from each square mile of drainage area, or one-half an annual rainfall of 42 inches, which is a fair average for the larger part of the United States, east of Kansas and Nebraska, rising, according to Blodgett, as high as 50 and 55 inches, in parts of the Southwestern States, but a safe estimate for the area of drainages from the great Appalachian range, which is as wide an area as we propose to consider in this paper.

It will be readily seen that this annual rainfall of 42 inches amounts to nearly 732,000,000 gallons on a square mile, so that 1,000,000 gallons per day is almost exactly half of it. To secure this half, however, requires the most complete and perfect system of storage basins possible, and it is not safe to

THE PAWTUCKET DAM AT LOWELL, MASS., U. S. A.

calculate on such an amount as being available for water power by any possible and economical means of storage.

It is possible, however, by practicable means of storage to secure about one-third of the rainfall, and as water for power purposes is usually measured in cubic feet per minute, or per second, instead of gallons, we will adopt that mode of computation.

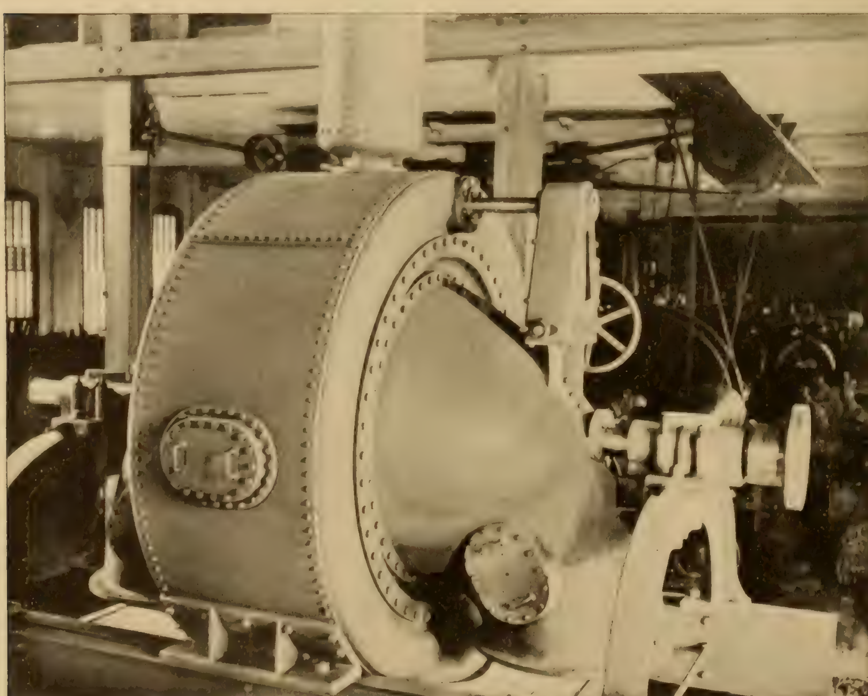
An annual rainfall of 42 inches is equal to 267,409 cubic feet per day on a square mile, or 3.09 cubic feet per second, and if we take one-third of this, or 1 cubic foot per second, from each square mile of drainage area, we arrive at the supply which can usually, by the aid of storage, be relied upon.

The late James B. Francis, for many years the engineer of the Locks and Canals Company, at Lowell, on the Merrimac River, once gave me the following data, as the result of many years' observation of the flow of the Merrimac River, which, however, does not take in the few days of "spring freshets," when the snow is going off from the mountains, and the river is so high and swollen as to be practically unmeasurable :—

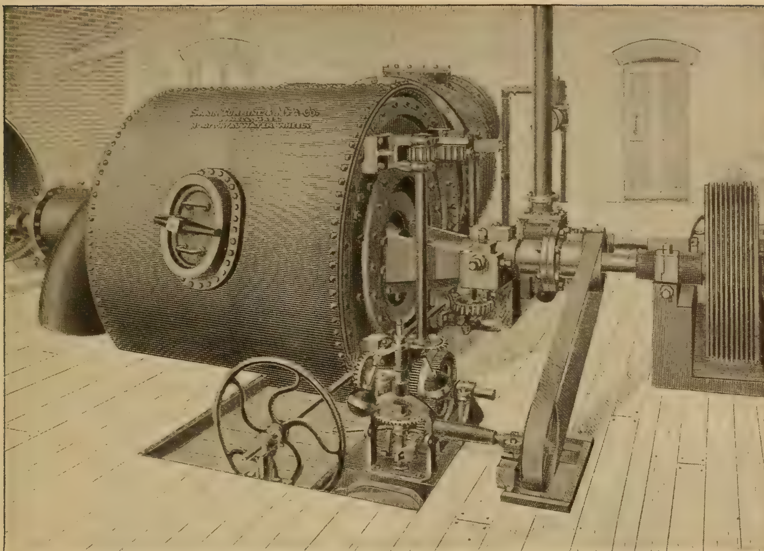
Spring flow, = 90 cubic feet per minute per square mile.
"June flow," about the average, 55 cubic feet per minute per square mile.
Minimum flow in August and September, 30 cubic feet per minute per square mile.

The minimum flow has, however, been less than that once or twice in recent years, as, in 1881, it was only 26.7 cubic feet per square mile drainage area, or 0.445 cubic feet per second. This diminution has been due to the destruction of the forests around the head-waters of the river, and such forest destruction must be borne in mind by every engineer as a probability, when making estimates on a projected water-power.

It will be seen that these 30 cubic feet per minute, or 0.50 cubic feet per second, the minimum flow, are but one-sixth of the rainfall, and in order to



A 1200 HORSE-POWER TURBINE, BUILT BY MESSRS. JAMES LEFFEL & CO., SPRINGFIELD, O., U. S. A.



A HORIZONTAL WHEEL, BUILT BY THE SWAIN TURBINE & MFG. CO., LOWELL, MASS., U. S. A.

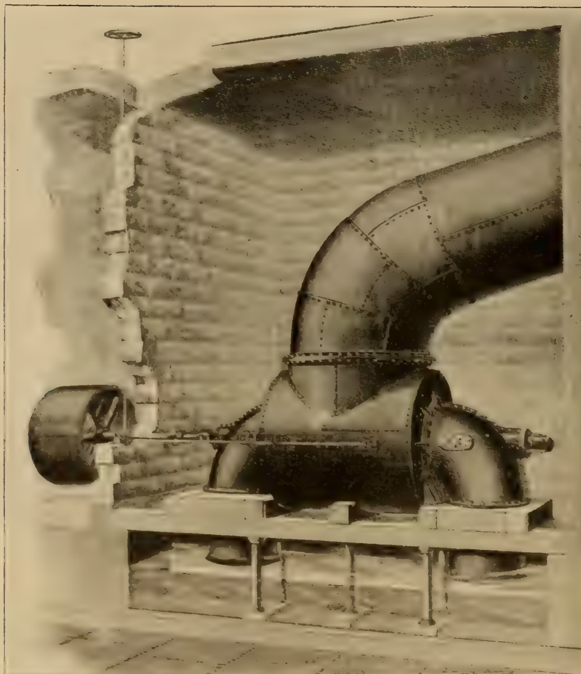
secure the one-third, which I have considered as available, a sufficient "pondage" must be secured above the dam, at the proposed water-power, or in some other convenient location, to store the night flow, if the water is used in the daytime, or *vice versa*, so as to get a double quantity during working hours without too much diminution of the working head.

This is practically accomplished at Lowell, where the observations on the water-power of the Merrimac River have been longer continued and are more complete than any others of which I am aware, by the pond made by the dam. This pond is 18 miles long, with an average width of 500 feet. The drainage area of the Merrimac, above Lowell, is 4093 square miles, and if we take the minimum flow of 0.50 cubic feet per second, we have a total flow of 2000 cubic feet per second.

Col. James Francis, who has succeeded his father as agent and engineer of the Locks and Canals Company, informs me that, with 3 feet of "flash boards" on the dam, giving a fall of 34 feet, they can store in this pond, at a depth of 1.50 feet, 71,874,000 cubic feet of water, which, if drawn down the 18 inches in 10 hours, would give them 6165 horse-power, which, added to the daily flow of the same 2000 cubic feet, would give, at low water, a total of 12,330 horse-power. The original estimate of the power available at Lowell was 10,000 horse-power on 30 feet fall; but by raising the dam above, and removing obstructions below, this power has been increased, as shown.

The net effect of the present turbines in Lowell is here taken at 80 per cent. There are, however, in place, at Lowell, turbines enough to utilise 20,000 horse-power, for which water is furnished for a portion of the year, but which have to be supplemented by steam-engines to supply the deficiency, when the water is reduced to the minimum flow, as above quoted.

In addition to this, the mills at Lowell, Lawrence and Manchester, N. H., have also derived great benefit from the use of the water stored in Lakes Winnepesaukee and Winnesquam, in New Hampshire, where the outlets were deepened, and weirs and gates put in below, enabling the water-power companies to draw down these lakes in the summer to a depth of 12 feet below



A PAIR OF 30-INCH VICTOR TURBINES ON A HORIZONTAL SHAFT, BUILT BY THE STILWELL-BIERCE & SMITH-VAILE CO., DAYTON, O., U. S. A.

the full height in spring, or 6 feet below their normal summer level. The area of these lakes above the Lake Company's dam is 71.8 square miles, and Colonel Francis gives me the following data of the amount of water furnished by them for several consecutive years :—

Year.	Horse-power furnished for 3 months.	Depth drawn at lake.
1878	659	4.20 feet.
1879	809	5.16 "
1880	1,299	8.28 "
1881	1,600	10.20 "
1882	1,506	9.60 "
1883	282	1.80 "
1884	1,845	11.76 "
1885	69	0.44 "
1886	1,067	6.80 "
1887	0	0. "

The variations in seasons is seen to be considerable.

Leaving this branch of the subject, with the repetition of the statement that, by storage, one-third of the rainfall can be relied on for power for day or night, I now take up the question of turbines.

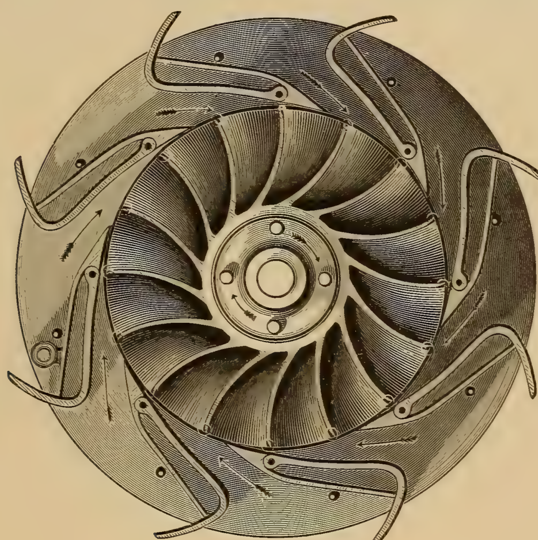
The modern turbine is the evolution of ages from two distinct types, one of which delivers the water in a tangential direction to radial arms or vanes, projecting from a central shaft, without confining it in any way ; the other conveyed it in a closed tube to hollow radial arms, through which it passed, and, leaving them in a tangential direction, gave, by the reaction pressure, a rotary motion to the whole apparatus.

We can trace both systems back to such remote antiquity that it is useless to attempt to find the origin ; and as the principal developments of both have been made within the present century, we need go back no farther. As we shall devote much less time to the second of these types, or the "outward discharge," we shall consider it first, and simply refer to the well-known "Barker Mill," or the "Whitelaw & Sterret," sometimes called the "Archi-

median" wheel, as the first modern type of this style.

In 1827, Mr. Fourneyron applied this principle of the outward discharge from a pipe to a wheel with curved buckets placed outside of the apertures of discharge, so as to receive the water in a direction perpendicular to the first and inner element of the curve, which appears to be practically cycloidal, and which, revolving from the action of the water, finally discharges it at its outer element at the circumference, with its force exhausted; *i. e.*, the best results obtained from this form of turbine were shown by Mr. Francis, in his "Hydraulic Experiments," to be when the circumference of the wheel at the point of discharge had reached the velocity due to the water under the fall, or 62 per cent., of the theoretical velocity due the head, from the action of gravity, this being the result of what is known as the "contracted vein." At this velocity of the wheel the water falls away dead into the pit, to take a new direction due to the fall in the "tail-race."

In the Fourneyron turbine, the tube, or feeder, which supplied the water, was closed at the bottom by a concave cone surrounding the wheel shaft, which passed up through it in a pipe, and was not exposed to the water. This cone was surrounded by a number of guide plates, curved like the buckets, but in the opposite direction, and fastened to the cone; and these delivered the water to the buckets in the proper tangential direction. This first turbine of 1826 was followed by another in 1834 of 7 or 8 horse-power, which worked at times under a head of only 9 inches.



SECTION OF CASE OF THE NEW AMERICAN TURBINE, MADE BY THE DAYTON GLOBE IRON WORKS CO., DAYTON, O., U. S. A.

Then came several others, under higher heads of 63, 79, 126, and 144 feet respectively, giving from 71 to 87 per cent. net effect of the power of the water.

In 1837 came the celebrated one of St. Blasien, 20 inches in diameter, weighing 105 pounds, under a head of 72 feet, and this was followed by one of 13 inches diameter, under a head of 354 feet. The width of this wheel across the buckets was only 0.225 inch, and it made from 2200 to 2300 revolutions per minute. It is said to have driven 8000 cotton spindles, with the other accessory machinery, which

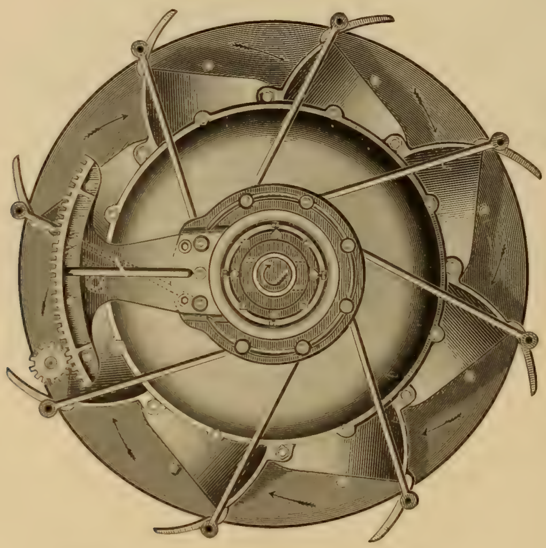
would require from 100 to 120 horse-power, and to have given from 80 to 85 per cent. net effect. The apertures of the buckets were so small, however, that the water was all filtered before entering the feeder, to avoid clogging them.

The success of these wheels led to their introduction to this country by the late Uriah A. Boyden, who placed the first ones in Lowell, in 1844, and these were rapidly followed by others, until their use became almost general in the large manufacturing towns of New England. Those built under Mr. Boyden's instructions gave as high as 80 per cent. net effect, and he claimed to have got 88 per cent. at the Atlantic Mills in Lawrence.

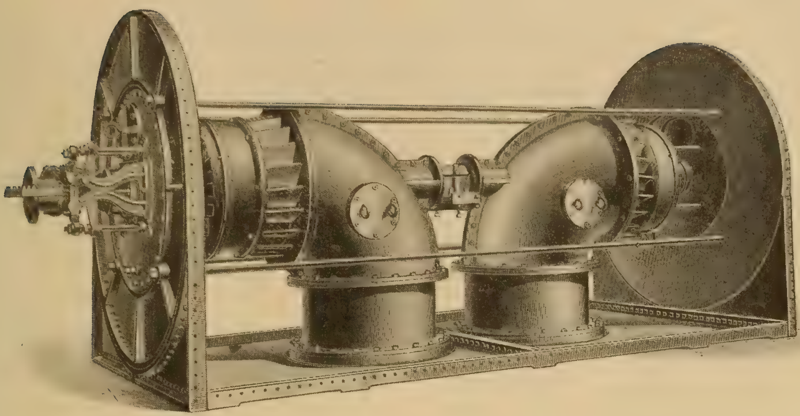
Their manufacture was taken up by a number of builders, but they did not all obtain such high results, and owing to the multitude of buckets, with the small apertures, they were liable to become choked by chips and leaves and other floating obstructions, not to speak of fish, for at Fall River the first turbines are said to have been stopped by eels, on the annual migrations to the sea, from Watuppa Lake.

The net effect at partial gate was also very poor, owing to cutting off the water by the sharp edge of a cylinder.

Attempts have been made to obviate this by introducing diaphragms in the buckets, so that only a part of the bucket is affected by this sharp cut-off, and this is shown in the Swiss turbines introduced at Niagara Falls, but this division only reduces the dimensions of the apertures, and renders them more liable to choke from obstructions. This form of wheel, as built by Mr. Boyden, was also enormously expensive, and they have generally given place, as they wore out, in forty or more years' use, to the "inward and downward flow" turbine, which we shall now proceed to trace. This, as we said in the outset, comes from the old "flutter-wheel" of radial vanes inserted in a central shaft, which supported a grindstone, or "millstone," on top of it, and which is one of the earliest traces of mechanical application of force to be found in history. India, Egypt, Syria, and Europe all appear to have used this primitive water-wheel to grind their corn. It is impossible to



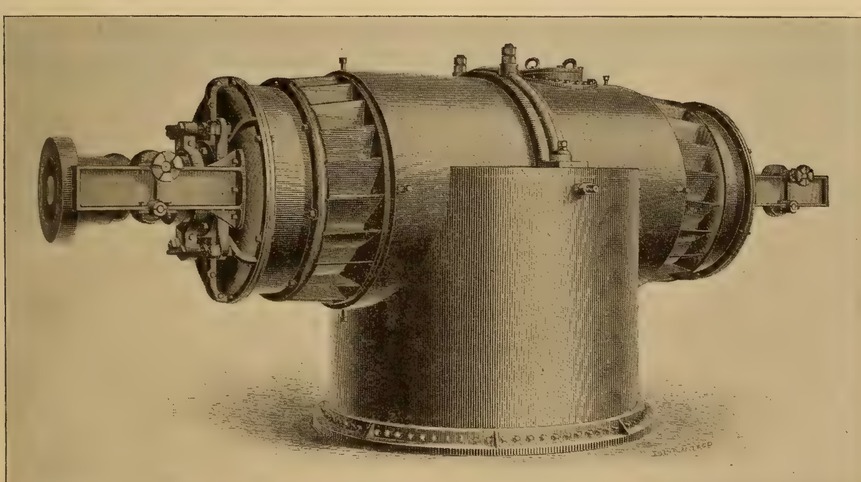
THE NEW AMERICAN TURBINE CROWN PLATE AND GATE-OPERATING MECHANISM.



A PAIR OF TURBINES DISCHARGING THROUGH SEPARATE DRAFT-TUBES, BUILT BY THE RODNEY HUNT MACHINE CO., ORANGE, MASS., U. S. A.

determine when the modifications of this form began, but, in 1804, a patent signed by Thomas Jefferson was granted to Benjamin Tyler, of Lebanon, N. H., for "an improvement in water-wheels," in which he claimed "hooping the wheel with iron hoops," and specified the proper angle at which to set the buckets, "made of winding timber."

Similar improvements were early made in the mountainous districts of France, where metal buckets, curved either vertically or horizontally, were bolted on a central shaft, and were known either as "*rouets à cuve,*" or "*rouets volants,*" and in common parlance with us were known as "tub wheels." The water was applied to all these wheels "tangentially," by a trunk or spout which delivered it at the circumference. Next, this trunk was made in the form of an Archimedian scroll, which applied the water equally all around the wheel, the top being closed, and the discharge at the bottom. A wheel of this sort was patented by John Tyler, grandson of Benjamin above referred to, in 1855.



ANOTHER PAIR OF RODNEY HUNT TURBINES ON A HORIZONTAL SHAFT.

I have no record of the dates of the European improvements in this direction, but, as early as 1843, Elwood Morris, of Philadelphia, experimented with and reported on what is generally known as the "Jonval turbine," in which the radial buckets are curved vertically, and the water directed to them by a set of stationary guides, curved in the opposite direction, and fixed to the interior of the tube or feeder which supplied the water. This form of wheel has also been known as the "Koechlin" and as the "Froment" turbine; the name of "Jonval," I believe, applies properly only to the "draught tube" arrangement, which was patented in this country by Zebulon and Amasa Parker, of Licking, O., in 1840.

These wheels were sometimes, in cases of low heads, set directly in the bottom of the wooden flume or forebay, in other cases supplied by an iron feeder pipe. The Froment turbine, which the writer saw in the London "Crystal Palace" of 1851, was of the former character, and the gates were a series of "plungers," which fitted down between the guides. J. P. Collins, of Norwich, Conn., has adopted this form of gate; others, as Mr. Geyelin, of Philadelphia, have used what is known as the register gate, a term derived from the common hot-air heating apparatus. Still another form has been a sliding telescopic tube, outside, which throttles the water after leaving the wheel, and seems to the writer objectionable, but has been applied to the turbines at Niagara.

This class of wheels, known as the "downward flow," has proved effective and economical, and they are particularly suited for large and constant powers at low heads, but are deficient at partial gate, if the gate is of the register or telescopic pattern. The writer has obtained 84 per cent. net effect, with two "Geyelin" turbines, in different localities, when at "full gate."

We must now turn to a different form of wheel, the "inward flow," patented in 1838 by Samuel B. Howd, of Geneva, N. Y. In this the action of the Fourneyron wheel is reversed, and the converging guides, which were straight, were placed ouside the wheel, which had curved buckets, revolving inside the guides, and was, in fact, only one form of the old "tub wheel." Mr. Francis has stated that a similar wheel was suggested by General Poncelet, in 1826.

In the Howd wheel, the regulating gates were placed outside the guides or "chutes." The buckets were cast-iron, fastened by bolts to wooden top and base plates, and the discharge was central.

In 1849 Mr. Francis took this matter up, and built, for the Boott Mills in Lowell, an inward discharge wheel, in which he employed the carefully designed curves of the "Boyden" wheel, and which gave excellent results, nearly equal to those of the outward discharge.

This type of inward discharge gave much greater facilities for operating the gates, and was followed by a number of variations, notably the "American Turbine," of Stout, Mills & Temple, of Dayton, O., in which the form of gate adopted gave much better results than were obtained when partially closed, by the cylinder between the guides and buckets, which Mr. Francis copied from Mr. Boyden. This wheel at the Boott Mills lasted until 1875, when it was replaced by a "Swain wheel." In 1855, A. M. Swain, a mechanic who had been employed at the Lowell machine-shop in the construction of the Boyden and Francis wheels, conceived an idea which produced the prototype and exemplar of all the modern American turbines. He combined the inward and downward flow wheels, curving the buckets both laterally and vertically, and discharging the water mainly downward, where a reversed curve in the base on which the wheel rested, threw it outward again, so that the path of the water was a semicircle. He adopted a form of gate which, instead of cutting off the water abruptly, closed the orifice by which it entered the wheel, by lifting the lower side of the tube, so as to contract the

passage, which still retained a rounded aperture. The result produced by this was marvellous; instead of 30 per cent. effect at part gate, or half-water, he got 66 per cent., and 83.4 per cent. at full gate, when the wheel was finally perfected in 1875.

The Swain wheel had, however, given an excellent result as far back as 1862, and from that date down to about 1878 the number of turbines was legion, in all sorts of variations of curve of bucket and form of gate, but all containing the same general features of inward and downward discharge. Of these, the Leffel wheel combined both forms of bucket, separated by a diaphragm in the same wheel, and has given excellent effects.

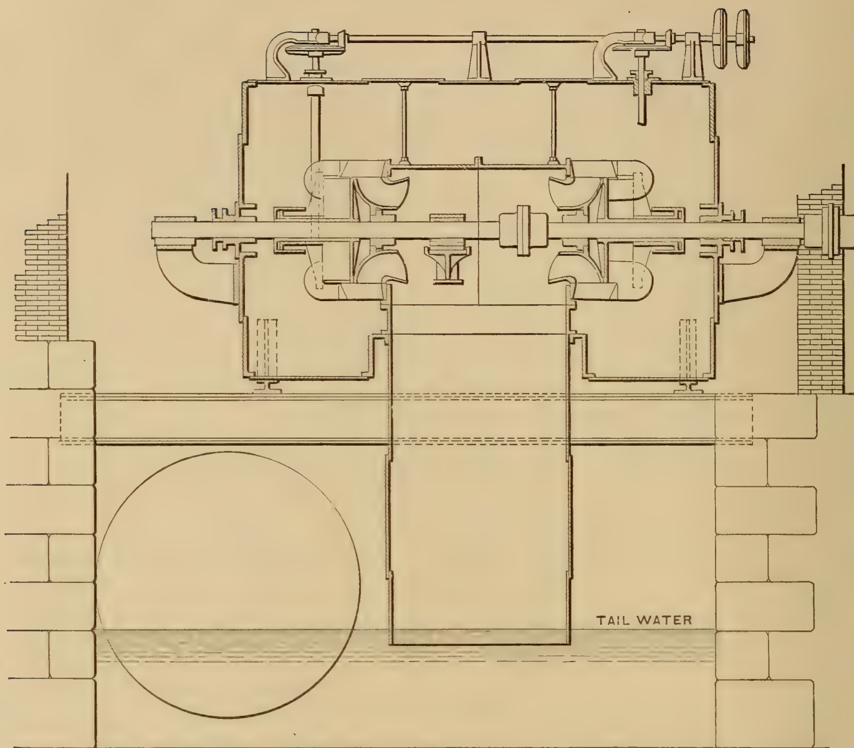
The general result of this change from the Fourneyron type, as first introduced, has been to furnish the public with turbines of equal power, in one-half the space and at one-fifth the cost, being single castings of iron or bronze, instead of built up of many parts. The general outline of evolution, beginning with the Swain wheel, has been that of fewer and deeper buckets, with wider openings, to avoid obstruction by floating matter, and in some of the wheels, like the Hercules, the narrow openings of the "chutes" have been retained, preventing such matter from entering the wheel itself.

This latter wheel brings us to the date of 1876, when what is known as the "new departure" wheels were introduced. The first of these was the "Hercules," designed by John B. McCormick, of Brookville, Pa., who brought it to the Holyoke Testing Flume to be tried, and the results were such that the Holyoke Machine Company at once entered into its manufacture. The principal feature of this wheel was a much smaller diameter, with longer buckets and deeper openings, for any proposed amount of power.

This wheel was at once followed by the "Victor," made by the Stilwell-Bierce and Smith-Vaile Co., of Dayton, O., on the same general lines, but differing in form of bucket and gate; and many of the older wheels have been since changed or improved in the same direction, and the following table will show the difference in quantity of water used and power obtained by a number of wheels of nearly the same diameter, under the same head of twenty-six feet, beginning with the "Boyden Fourneyron," and ending with the "Victor:"

	Inches Diameter.	Cubic feet Water per sec.	Horse Power.
Boyden Fourneyron	36	22.95	55
Risdon	36	35.45	89
Risdon "L. C."	36	48.27	121
Risdon "D. C"	36	80	199
Leffel, Standard	35	40.45	96
Leffel, Special	35	60	148
Tyler	36	40.7	95.8
Swain	36	58.2	140
Hunt, "Swain Bucket"	36	48.8	121
Hunt, New Style	36	98	239.74
Leffel, "Samson"	35	109.1	264
"Hercules"	36	107.6	253.5
Victor	35	108.8	266

This enormous difference in productive effect in wheels of the same diameter shows the great economy of the later type of turbines, particularly as all the wheels above named have a proved efficiency of 80 per cent., and some of them have given more; such as 87 per cent. for the Risdon, tested by Mr. Edward Sawyer, of Boston, at Crompton, R. I., and by the writer at the Centennial; 87 per cent. for the Hercules, tested by Professor Thurston; 84 per cent. for the Collins, by the same authority; 84 per cent. nearly for the Swain, by Mr. Francis; 84 per cent. for the Geyelin and the Hunt, tested by the writer, and 88 per cent. for a 15-inch "Victor," by the same, but this was so small a wheel that the test cannot be depended on. Later tests of large wheels at the Holyoke Flume give over 80 per cent., and to these may be added the "Success" of E. Morgan Smith, York, Pa., and the "Humphrey," Keene, N. H., and the wheel of Gates Curtis of Ogdensburg, N. Y., also the "New American," of the Dayton Globe Iron Works, Dayton, O. Here all questions of selection must be governed by other reasons than that of mere efficiency, as all the above seventeen wheels have been proved to give 80 per cent. or over net effect. Nearly all these wheels have been adapted to horizontal shafts, for high



A PAIR OF 43-INCH TURBINES, BUILT BY MESSRS. T. H. RISDON & CO., MOUNT HOLLY, N. J., U. S. A., FOR THE NASHUA MFG. CO.

heads, where the belt pulleys can be kept out of water, and so far as they have been tested show no difference in economy from that given on vertical shafts. A "Hunt" wheel, tested by Mr. Francis *in situ*, in a mill at Lowell, varied only a fraction of 1 per cent. on a horizontal shaft, from the result obtained on a vertical one by Mr. Herschel, at the Testing Flume in Holyoke.

While the writer has expressed a preference for the "downward flow" wheel when the head was low, and bevel gears necessary, he would prefer the new type of small diameter wheels for horizontal shafts under high head, as they give a greater initial velocity to the shafting, the friction of bevel gears is avoided, and, if set in pairs, to thrust against each other, step friction, which is very destructive in muddy streams, is also done away with.

The first instance in which turbines were placed in pairs in this manner, in the writer's memory, was in 1875, when A. M. Swain installed a pair at Ticonderoga, N. Y., which were very successful. Since then all the prominent wheel builders have adopted it, and it has become very general in all cases where the head was sufficient to keep the pulleys out of water. It also gives the advantage of easy and immediate access to the wheel for examination or repairs, by a manhole in the case, if the head-gates to the feeder are closed. The writer installed a pair of Risdon turbines for the Nashua Manufacturing Company in this way some time since, and asking the man who had charge of them, after two years' use, "If anything had been required to be done to them?" he answered, "Nothing but to oil the stuffing-boxes, and open and shut the gates." Like all other waterwheels, the turbine is somewhat slow in answering to regulation under a variable load, as it takes more time to open

and close the gates than it does to trip the "cut-off" in a Corliss engine, but both the "Snow" and "Schofield" governours are very effective, and can be recommended.

When we come to the matter of cost of water power, we find it to vary much in different localities, according to the expense of development. The cost at Lowell, when the first "mill powers" were opened, had been only $40 (£8) per horse-power, for dam, land, and canals. This was increased $50 (£10) per horse-power by the new canal, which gave more certain head, and enabled the mills to use the surplus water which ran to waste part of the year, and the total cost has probably been $100 (£20) per horse-power, to which another $100 is to be added for the expensive Boyden wheels and massive masonry pits. At Augusta, Ga., the canals, nine miles long, cost the city, which leases the power, $90 (£18) per horse-power. At Columbia, S. C., for five miles of canals the cost to the city has been $72 (£14 8s.) per horse-power.

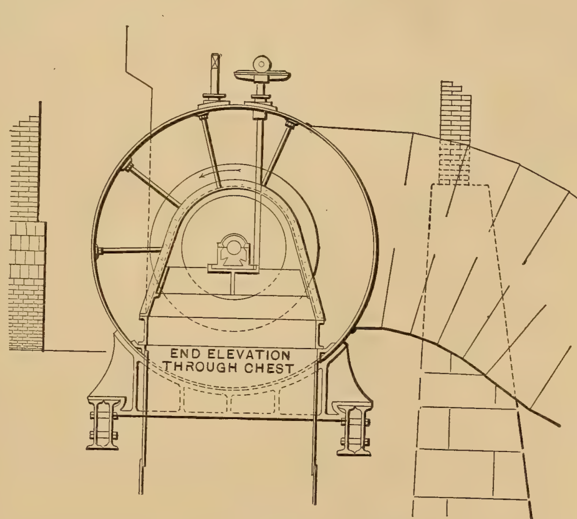
In many cases of smaller enterprises it has been less than $50 (£10) per horse-power, and the total cost, including wheels and pits, less than $100, and we will now give the data of the cost of water power as developed within recent years at three different points, showing the outlay, and a fair allowance for interest and running expenses.

The first instance we shall give is that of the Concord Water Power Company, on the Merrimac River, at Concord, N. H. Here the power developed is at a minimum 3300 horse-power, on an average 5000 horse-power from a fall of 22 feet. The wheels are "Rodney Hunt" turbines, set in pairs on horizontal shafts of four hundred horse-power each. The cost of the plant has been as given in the following table:

700 acres Land, and Flowage Rights	$20,000	£4000	
Dam and Abutments	141,015	28,203	
Canal, 60 feet wide	27,363	5,472	12s.
Head Gates	16,675	3,335	
Waste Weir	5,220	1,044	
Making an investment for water of	$210,273	£42,054	12s.

or $63.72 (£12 14 s. 11d.) for the minimum amount of power, or $42.05 (£8 8s. 2½d.) for the average amount of power. To this is to be added, pits and foundations, put in for 2000 horse-power, $15,000 (£3000), or $7.50 (£1 10s.) per horse-power. Wheels put in for 1600 horse-power, $12,225 (£2445), or $7.66 (£1 10s. 8d.) per horse-power, making a total, for the minimum flow of water, of $78.88 (£15 15s. 6½d.) per horse-power, and for the average flow of $57.75 (£11 11s.) per horse-power.

Now, if we base our calculation of cost on the minimum flow, and allow interest, 5 per cent., sinking fund, 2½ per cent., repairs, 1½ per cent., taxes, etc., 1 per cent., we get a total annual cost of 10 per cent., or $7.89 (£1 11s. 7d.) per horse-power, to which add oil and attendance, 75 cents (3 sh.), making $8.64 (£1 14s. 7d.).



END ELEVATION OF RISDON TURBINES SHOWN ON OPPOSITE PAGE.

As this power is to be transmitted, in part, at least, to Concord by electricity, the cost of such transmission,

on which I do not assume to be authority, will have to be added to this. If, on the other hand, it is to be partially used near at hand, it is safe to say that the cost of transmission by shafts and belts would not increase it to over $10 (£2) per horse-power.

If we assume the average flow of 5000 horse-power the cost of the power of the wheels would be only $5.72 (£1 2s. 11d.), but we should then require the additional expense of a steam plant, and its operation, to produce the 1700 horse-power deficiency at low water.

We will now take a large southern mill, the John P. King, of Augusta, Ga. Here the water is purchased of the city at a rental of $5 (£1) per annum per gross horse-power. The wheels are 3 Geyelin turbines, on vertical shafts with bevel gears, estimated at 1835.5 gross horse-power. These wheels, by my own test *in situ*, netted 84 per cent. Calling the average 80 per cent., it gives 1468 net horse-power. This cost of plant was for wheel pits, 42 feet deep, in rock, head race, 200 by 40, tail race, 800 feet to river, about $25,000 (£5000), and the wheels and jack shaft cost the same, or $50,000 (£10,000) in all. This, for 1468 net horse-power, is $34.20 (£6 16s. 10d.) per horse-power, or, at 10 per cent., $3.42 (13s. 8½d.); water rent, $5.50 (£1 2s.) on 1835.5 gross horse-power, equal net, $6.88 (£1 7s. 6½d.); attendance and oil, 75 cents (3 sh.), making a total cost of $11.05 (£2 4s. 2½d.).

The next case is also a southern one, that of the Columbia Mills, at Columbia, S. C. Here the water is also leased at a rental of $5 (£1) per horse-power. For quantities less than 500 horse-power, the charge is $7 (£1 8s.). The fall is 27 feet, and the power is furnished by Victor turbines, on horizontal shafts, and is transmitted by electricity to the mills.

Quicksands made the wheel-pits very expensive, by the quantity of concrete masonry required, so that for all expenses of pits, races, power-houses, etc., we have $55,000 (£11,000) for 2000 horse-power. The wheels cost $20,000 (£4000) more, so that we have a total expenditure of $75,000 (£15,000) for 2000 horse-power, or $37.50 (£7 10s.) per horse-power. This, at 10 per cent., as before, gives $3.75 (15sh.) per horse-power; water rent, $5 (£1) per horse-power; attendance and oil, 75 cents (3sh.), making a cost at wheels of $9.50 (£1 18s.) per horse-power.

As the water rent paid in the last two cases covers interest and depreciation, while the cities which furnish the water also obtain their own supply for other purposes, it will be seen that it covers the cost, and that the estimate of Mr. Samuel Batchelder, fifty years ago, that the cost of water-power in Lowell, including land, was under $15 (£3) per annum per horse-power, was substantially correct, and will cover the cost of water-power with modern turbines, under fair circumstances, to-day, with plenty of room to spare for heating.

A CARBORUNDUM FURNACE AT WORK.

CARBORUNDUM.

What it Is and How it Is Made.

By Francis A. J. Fitzgerald.

THE scene of one of the delightful stories of Jules Verne is laid in the African diamond mines, and the hero is a French engineer whose hobby is the manufacture of diamonds. He fails in many of his experiments, which consist in heating carbon in a very hot furnace in the hope that it may be vapourized or liquefied, and then crystallize into diamonds when cooled. Finally, when he opens one of his furnaces he finds in it a beautiful diamond. This becomes the cause of all kinds of exciting adventures afterwards and, in the end, the engineer finds out, to his disgust, that the diamond is really a natural one and had been placed in the furnace by his faithful servant who wished to save his master the disappointment of repeated failures in his experiments.

Mr. E. G. Acheson, the inventor of carborundum, and the president of the Carborundum Company, which has recently started its works at Niagara Falls, has had more success than Jules Verne's hero, for, though he has not invented a way of making diamonds, yet carborundum is closely related to diamonds, not only in the materials of which it is composed, but in many of

A CARBORUNDUM FURNACE OPENED, SHOWING THE CARBORUNDUM.

its physical qualities, such as hardness and beauty of appearance.

It is a well known fact that of all known substances the diamond is the hardest, and it is this quality that gives it a value quite apart from its value as a precious stone. Of late years the immense value of hard substances which can be obtained in large quantities, and made up into suitable forms to be used as abrasives, has been fully recognised. Thus it is that an immense amount of money is spent every year in the mining of emery and corundum, which are made up into wheels and special shapes and are used in all workshops of the world. Neither emery nor corundum is as hard as the diamond, and if the latter, therefore, were not so scarce it would be of great value as an abrasive and would undoubtedly do away with the use of all others.

Considerations like these occupied Mr. Acheson's mind for some years before 1890, and kept him constantly on the lookout for something that would suggest a method of manufacturing the crystalline form of carbon, commonly called diamond, or, at least, of obtaining a crystalline form which would equal the diamond in hardness. Finally, he conceived the idea of heating together carbon and clay, so that when the latter was fused, the carbon would be dissolved in the melted silicate of alumina, of which clay is chiefly composed, and then, when it was cooled, carbon crystals would be formed.

In the year 1891 an electric light company was formed at Monongahela, Pennsylvania, U. S. A., which also had for an object the experiments which Mr. Acheson had devised. In his first experiment he made his furnace of an iron bowl, lined with carbon and filled with a mixture of carbon and clay. Into the middle of this mixture a carbon rod was introduced and connected to one of the wires from a dynamo, the other wire being attached to the iron bowl. When the current from the dynamo passed through the mixture, the latter soon became very hot and then apparently a violent chemical reaction took place.

When the current was turned off and the mass was removed from the bowl, it was broken open and examined, with the result that a few, very hard crystals of a bright blue colour were found. The

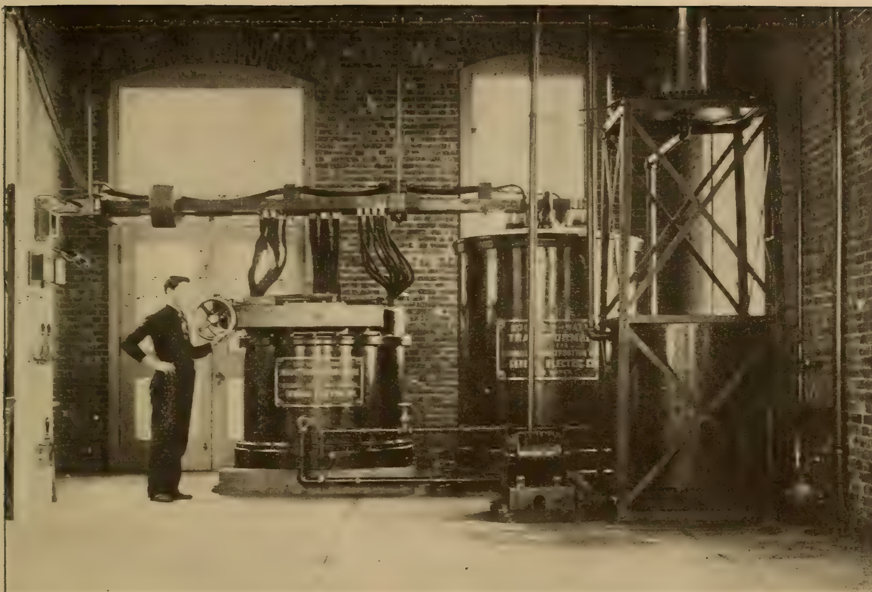
crystals, however, were very small and it was thought that better results might be obtained by using a larger furnace and arranging better conditions. Accordingly, the iron bowl was replaced by a furnace, built of refractory bricks, its internal dimensions being 10 inches in length, 4 inches wide and 4 inches deep. Carbon rods were introduced into each end of this furnace; the latter was filled with the mixture, and the current was then turned on. It soon became evident that the crystals were not crystallised carbon, but a compound of carbon and some other material. From the general appearance of the crystals and from the materials used in the manufacture, it was supposed that they were made of carbon and aluminium; hence the name carborundum, being a combination of carbon and corundum. Since that time

ONE THOUSAND HORSE-POWER STATIC TRANSFORMER AT THE WORKS OF THE CARBORUNDUM CO.

carborundum has been examined chemically and has been found to be a compound of carbon and silicon; therefore, it is properly called carbide of silicon.

After the crystals were removed from the furnace they were ground up to a fine powder and carefully sifted. The yield of carborundum powder from one of these early furnaces amounted to about a quarter of a pound a day. It was sold to lapidaries by the carat, and, later, to valve grinders by the pound, one pound costing $10, or about £2. The valve grinders found that it would

THE INTERNAL MAKE-UP OF THE TRANSFORMER. THIS TRANSFORMER REDUCES THE PRESSURE OF THE TWO-PHASE ALTERNATING CURRENT FROM 2400 TO 185 VOLTS.



THE INTERIOR OF THE TRANSFORMER ROOM.

do far finer work than emery, and as a workman used only one-eighth of an ounce a day, it was worth while paying this high price.

As the great value of carborundum came to be better recognised, the demand for it increased, and a fair-sized plant was put up at Monongahela, and there carborundum was produced at the rate of about three hundred pounds a day. Soon this plant was found to be too small, and then the company decided to set up a plant on a large scale at Niagara Falls, where electricity could be obtained from the great dynamos of the Niagara Falls Power Company.

The works of the company at Niagara Falls are situated about a third of a mile above the power house, and just beside the works of the Pittsburgh Reduction Company. The first building to which the visitor to the works is taken is the stock building. Here are received the crude materials, the building being provided with a railway track connecting with the Niagara Junction Railroad, on which the loaded cars are conveyed to the various bins provided for the reception of their contents. These materials consist of sand from Ohio, salt from the salt works of New York State, coke from the bituminous coal fields of Pennsylvania, and sawdust from the saw mills of Tonawanda, near Buffalo.

In this building the mixing of these materials for the furnaces is carried out. The coke is ground up in a mill to a fine powder, and is then mixed, in a mechanical mixer, with the requisite amounts of sand, salt and sawdust. This mixture is next conveyed to the furnace building.

To one unfamiliar with the manufacture of carborundum, the first view of the furnaces is a surprise. The furnaces are of brick, built up into four walls, so as to form a rough, oblong, brick box, no mortar or cement of any kind being employed. The building contains five of these remarkable furnaces, each of which is about 17 feet long, 6 feet wide and 6 feet high. At each end of the furnace is a large bronze plate, to which are connected four stout copper cables. Beneath the floor of the furnace extend large bars of copper, carrying the electric current, and to these bars are attached the

PURIFYING THE CARBORUNDUM WITH ACID.

cables. Connecting with the inner surface of each of the bronze plates are sixty carbon rods, 30 inches long and 3 inches in diameter. The rods project through the walls of the furnace and form the terminals.

The mixture above mentioned is introduced into the furnace until it is about half full. The workman then builds a core, composed of small grains of coke, which serves to form a continuous electrical connection between the terminals. The core being completed, more of the mixture is thrown in until the furnace is full, when it is ready for the current.

Next to the furnace building is the transformer room. There the visitor sees the largest transformer in the world. The current supplied from the Niagara Falls power house is at a potential of 2200 volts, which is far too high to be of any use in a carborundum furnace. Accordingly, the great current of one thousand horse-power is supplied to the transformer, which converts it into a current with a potential of only 185 volts. Even then, however, the current is not ready for the furnaces, for it is absolutely necessary that when the latter are first started, the current should have a higher potential than 185, and after they have run for some time and are properly heated up, the potential should be lower than 185. It is for this reason that the current from the transformer is not taken directly to the furnaces, but goes first through a regulator, which alters the voltage simply by turning a wheel. Both the transformer and regulator would soon become very warm in handling such an enormous current, were it not that they are kept cool by a current of oil which is constantly pumped through them by a small pump, driven by an electric motor.

When the current is first turned on, no change is noticed in the furnace ; but after about an hour, gases begin to come off which, when ignited, burn with a blue blaze. After a few hours, the whole furnace is enveloped in a sheet of blue and yellow flames, and presents a beautiful appearance. The stranger would naturally expect that the heat from these furnaces would be very great ; but this is not the case, for even at a distance of only three feet from the furnaces the heat is not disagreeable. The reason is that nearly all the immense amount of heat developed is used up inside in bringing about the wonderful chemical change which produces carborundum.

After twenty-four hours the current is cut off from the furnaces, and the walls of the latter are pulled down.

No change is observed in the outer parts of the mixture except that the sawdust has been burned up and the salt vapourised. The mixture also has become caked and can be easily pulled off, leaving bare the mass of carborundum which has been formed round the core. When some of this is removed and a cross section of the carborundum is exposed, it presents a beautiful appearance, of which no photograph can give an adequate idea. Magnificent crystals radiate in lines from the core to a distance of from 10 to 15 inches.

These crystals are of all colours, red, green, blue, yellow and violet. The majority of them are small, but whenever any hollow has been formed, large glittering hexagonal crystals are found, some measuring half an inch on a side. They are subsequently ground down to powder, as previously stated.

After that they are placed in long tanks, filled with dilute sulphuric acid, which removes all impurities and washes them thoroughly. After that they are sifted and stored away in bins ready for use.

Carborundum is sold in various forms, such as wheels, hones, files, rubstones, knife sharpeners, scythe sharpeners, slips and cloth. To make up these various forms, the powder is mixed with a binding material, moulded, placed in hydraulic presses, and afterwards vitrified in kilns. At first, the largest trade in carborundum was with dentists, who, at an early date, recognised its great value. Now, however, it is seen that carborundum is far superior to emery, in that it will do work quicker and better than that material, saving both time and labour. This is one of the principal reasons why the carborundum company was forced to set up a plant on a large scale at Niagara Falls. Carborundum is produced there at the rate of about two tons a day, and even this will hardly be sufficient, so that probably before long the thousand-horse-power of current at present being used will be added to. With this in view, the plant has been constructed to accommodate three or four thousand horse-power.

THE ORIGIN AND EVOLUTION OF THE DROP HAMMER.

By F. C. Billings.

IT is within thirty-five years that the possibilities of the drop hammer and its work have been demonstrated. It is conceded that the American was first to conceive and perfect the idea of interchangeable and duplicate parts for such machines and mechanical movements as were likely to have a demand and, consequently, to be manufactured in quantities.

The American civil war was a prime factor to the incentive of this genius in the make-up of American workmen. With the enlistment of the armies came demands for arms that the facilities of the armories were inadequate to meet. The enlargement of existing armories and the acquisition of additional ones became imperative. With these increased facilities came the demand for skilled workmen whose services were of greater value to the government while they were working at the forge or bench, than they would have been at the front.

In those days brass castings were largely used for parts of small arms. Government specifications, however, called for pistol frames and component parts to be of wrought material. Skillful blacksmiths were wanted, and in such numbers that the demand soon exceeded the supply. It was here that the drop hammer first demonstrated its great possibilities. The machines of that period, as compared with those of

the present, were crude affairs, but with their aid the armories were enabled to increase their output many fold.

For many years there was but one establishment that made a business of drop forgings. Drop hammers were used almost exclusively in gun and pistol factories. The sewing machine industry created a demand for light forgings and some of the arms factories went into that business, and, later, many of the large sewing machine factories were equipped with their own drop forging plants. The success of the pioneer drop forging company induced others to go into the business, and to-day there are not less than twenty-five corporations in the United States engaged in the manufacture of this material, without mentioning those in the carriage hardware trade.

To the manufacturer of drop forgings, the past twenty-five years would seem to be divided into eras as follows :—the small arms, the sewing machine, the bicycle, the typewriter and the electrical era. The histories of the first two eras show that eventually the various and numerous corporations engaged in the business of those eras are resolved into two or three large concerns which recognise the economy of running their own forging plants.

The manufacturer of drop forgings has reaped the rewards of his industry from each era, and there is no reason to think that the history of the later eras will differ from the preceding ones. Therefore the time will come, probably, when he will be looking forward to the advent of flying machines to open a new field.

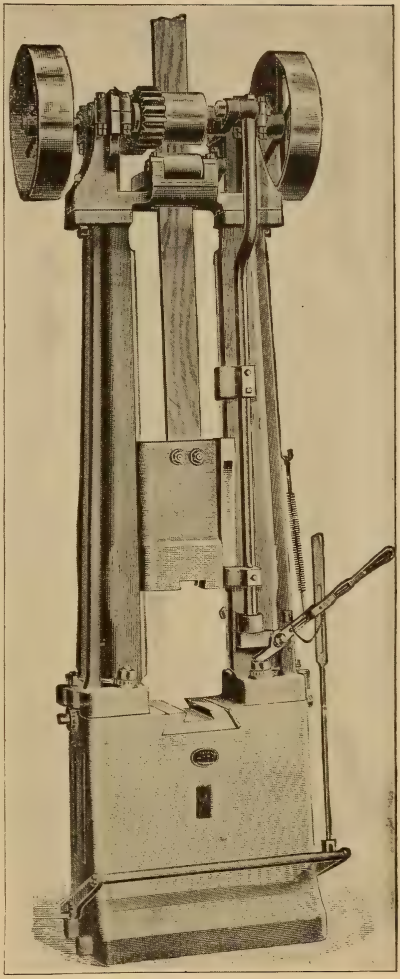
A DROP FORGING SHOP.

It is necessary to the manufacturer in any line, in order that he may arrive at the greatest possible output of which his plant of tools and machinery is capable, that his raw material should come to him in uniform shapes and sizes. This fact being recognised, the earliest efforts to produce uniform forgings brought forth what was termed the

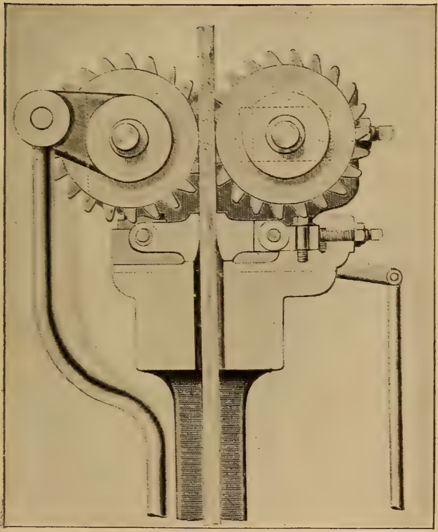
"jumper," which was merely a roughly constructed fixture, designed to hold the upper and lower dies in their relative positions. The forgings having been blocked or roughed out on the anvil, were placed between the dies of the jumper and the necessary force was supplied by a "striker" and as heavy a sledge as his strength would permit him to handle. The striker and his sledge were eventually supplanted by the first drop hammer, the fundamental principle of which was to drop a heavy weight, to which was secured the upper die, upon a base or anvil to which the lower die was secured.

The main principle of the drop hammer is the same to-day as it was at that time, and the detail in which the greatest opportunities for improvement have presented themselves is in the lifting mechanism. In the earliest designs the weight or hammer was lifted by a leather strap wound upon a drum, or by friction of the strap upon the face of one or more pulleys. This type of machine, generally known as the "poppet drop," is still manufactured for jewellers' and sheet metal work.

Another early lifting device was a continually revolving screw. A half nut, attached to the hammer, was thrown into engagement with the screw as the hammer struck its blow, and was thrown out of engagement when the hammer reached its highest point. Sometimes the half nut would not "mesh" accurately with the screw, and a beautiful chip would be turned off the entire length of the screw, causing a shut-down for repairs and augmenting the size of the scrap heap.

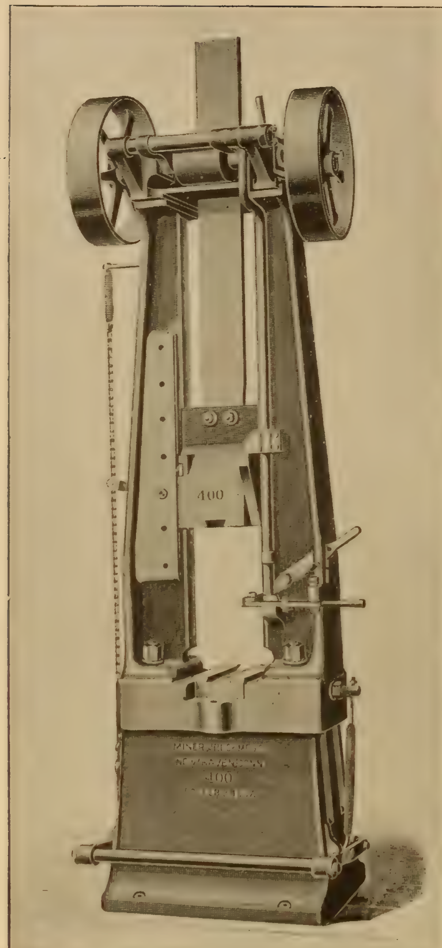


THE STILES FRICTION ROLL DROP HAMMER, BUILT BY THE E. W. BLISS CO., BROOKLYN, N. Y., U. S. A.



THE "LIFTER" OF THE STILES HAMMER.

In a later design the lifting of the hammer was accomplished by means of racks or long notched bars, extending down the sides of the uprights. By means of a revolving crank shaft at the

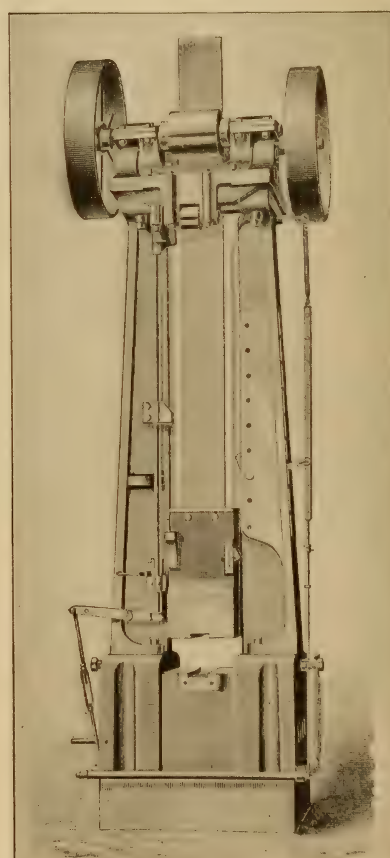


DROP HAMMER, BUILT BY THE MINER & PECK MFG. CO., NEW HAVEN, CONN., U. S. A.

head of the machine, those bars were given a vertical movement of about six or eight inches. A pawl in the hammer engaged with the notches in the bar, and the hammer was "hitched up" to the required elevation at the rate of about twenty feet per minute.

This hammer was so slow in operation that it was not possible for the operator to get more than one blow before losing the "heat;" therefore, the machine was built with four uprights and four hammers, mounted on one circular base, and the operator was enabled to get four blows by making a complete circumambulation of the machine. There are specimens of this type of machine still in existence and doing satisfactory work on special operations.

Next came the first approach to the modern machine, known as the "board lifter," the lifting being accomplished by means of friction on a leather strap working between two iron rolls revolving in opposite directions. One roll revolved in fixed bearings and was termed the "driving roll," the driving pulleys being attached to its shaft. This roll was provided with gears that meshed with gears of equal diameter on the driven roll, causing the latter to revolve in an opposite direction. The bearings of the driven roll were eccen-



ANOTHER HAMMER, MADE BY THE PRATT & WHITNEY CO., HARTFORD, CONN., U. S. A.

trics which, by an automatic action of the machine, were actuated by the hammer in rising and falling, causing the driven roll to work to and from the driving roll, thereby pinching and releasing the leather strap by which the hammer was lifted.

With various modifications and improvements this is the general form of lifter in use at the present time. Economy recommended a board in place of the leather strap. The gears have been generally discarded and each roll shaft is provided with a pulley and the rolls are driven, respectively, with an open and a crossed belt.

The modern drop hammer must be—well, say versatile. The hammerman should be enabled to keep his eyes, his mind and both hands on the bar of metal he is manipulating and, with one foot, so control the operation of the hammer that he can make it do all that a steam hammer can be made to do, namely, to strike short, quick blows, light blows or long, heavy blows. The machine should be as nearly automatic as possible and still be under the complete control of the operator.

It has generally been considered, by those who have had the supervision of a drop forging plant, that a drop hammer was a decidedly unsatisfactory tool to have around, being usually out of repair and requiring constantly a small machine shop to keep it in running order. Until within a few years there was more or less reason for this feeling. With the increasing demand for more cast-iron in machine tools, the drop hammer has not been overlooked. In the earlier machines, if the base was six times the weight of the hammer, it was considered adequate. For a long time the ratio of 10 to 1 was considered the right idea. To-day 15 to 1 is in demand, and experience seems to show that the heavier the base or anvil, the more satisfactory are the results as to the working and durability of the machine.

The uprights and castings throughout have been made heavier, but not in proportion to increase of weight in the base as that would have been unnecessary. The general result has not been such as to enhance the beauty of the machine, but the up-to-date drop hammer looks a business-like tool, capable of doing hard work and keeping it up.

Most of the recent improvements in drop hammers have resulted in increased efficiency and durability and a simplicity designed to facilitate repairs when such are necessary. There have been no radical changes from the original design of board lifter and it seems doubtful if anything can be conceived that will prove to be more economical and generally satisfactory in its particular line of work than this type of hammer.

JOHN I. THORNYCROFT, F. R. S.

By C. J. Cornish.

STUDENTS of the complex problem of heredity will find in the subject of the present notice a concrete example of specialised capacity, transmitted and enlarged in the inheritance.

Mr. Thornycroft's name became so early a synonymn for mechanical ability, that the question of birth and parentage would be one of no common interest, even did the facts not bear directly on the origin of such uncommon powers. But in this case they are very pertinent to the subject. He is the son of Mr. Thomas Thornycroft, the sculptor, whose wife, Mrs. Mary Thornycroft, followed the same art, with marked distinction and success, at a time when distinction in that art was not common among men and still rarer among women. In her case the talent was inherited ; for her father, Mr. John Francis, was also a successful sculptor, and it was while working in his studio that she met the fellow student, who became her husband. They left England to study among the Vatican marbles ; and it was in Rome, among the setting and surroundings of the sculptor's life, that the son, the subject of the present paper, was born in 1843.

But Mr. Thomas Thornycroft's interests were by no means limited to the work of idealising the human figure in marble and bronze. He was a man of great originality and singular force of character, and his natural instincts leaned almost as strongly in the direction of engineering as in that of his own profession. Born in one of the

THORNYCROFT'S SMALL BEGINNINGS AT CHURCH WHARF IN 1866.

great Cheshire farm-houses, each of which is, in a sense, a manufactory, he had, as a boy, encouraged and directed the use of machinery in the processes of the farm, and his studio was supplied with some of the appliances of a mechanical workshop. It was to generate the steam power for this that he first adapted the fan, which his son applied later with such astonishing results for the use of forced draught in the closed stokehold; and the fan in question was produced and exhibited by his son before the Institution of Civil Engineers, when the question of the first originator of the device was raised.

The connection of art and mechanics is a time-honoured alliance. We need only refer to the instances of Leonardo da Vinci, of Cellini, who fortified the gates of Florence, and of Albert Durer, who not only improved the ramparts of Nurenburg, but designed the mountings of the cannon, and the protective fittings of the embrasures. In the present case it is enough to indicate briefly, as has been done, the qualities of the parents whose younger son, Mr. Hamo Thornycroft, R. A., became a sculptor of renown and the elder a consummate engineer.

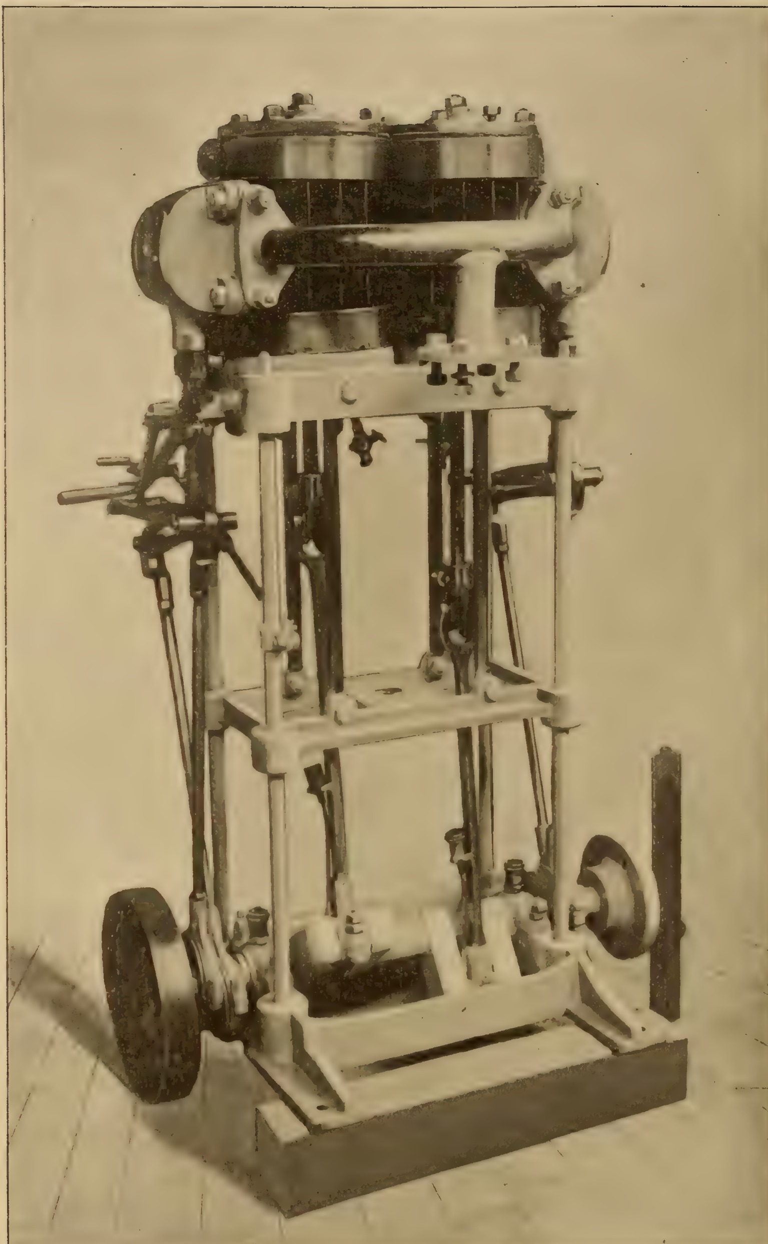
"The history of genius is the history of youth." So said Lord Beaconsfield. If genius be "untaught ability," then the aphorism is true. It shows early, but it seldom asserts itself in so striking and concrete a form as in the present instance. Technical education was then unknown. Mr. Thornycroft, as a boy, did not even live in the atmosphere of mechanical energy, which life in a northern manufacturing town among mills and machinery generates. But father and son were inseparable; the studio and its workshop were open to him; and the exhibition of 1851, in which both his parents exhibited sculpture, also contained the first representative collection of engines and machinery, in visiting which his father even then made him his constant companion. Mr. Thornycroft even now remembers these visits, and speaks of how he used to creep under the engines and machinery to satisfy his curiosity.

And at the age of seventeen Mr. Thornycroft built from his own designs, in his father's house, a steam launch called "Nautilus," which was 36 feet long by 5 ft. 10 in. beam. This boat he built of iron, and launched it on the Regent's Park canal. It was subsequently tried upon the Thames, and was easily able to keep up with the fastest racing eights upon the river.

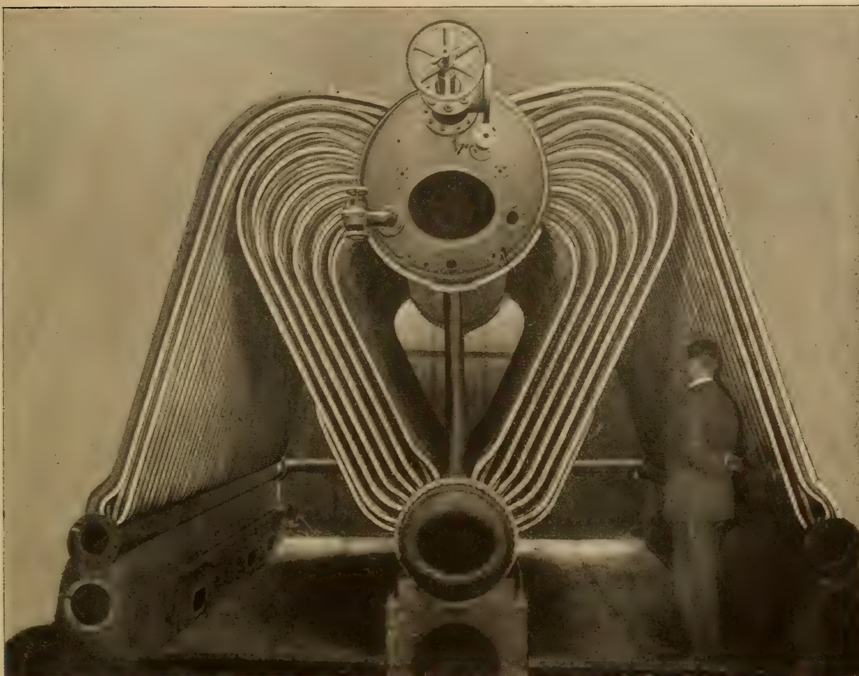
The success of the "Nautilus" aroused much comment and curiosity. Both the vessel and its engines were such as more than justified the public interest. In these, and in a model boat previously constructed, the young inventor had anticipated principles of design which guided the subsequent construction of the fast launches and torpedo boats of later years. The model boat, the "Annie," was provided with a closed stokehold and fan for forced draught, and was designed of great length in proportion to beam. The screw-shaft was so placed as to admit of the use of a large propeller, the blades of which revolved beneath the keel. The engines of the "Nautilus" were constructed mainly of hard tool steel,—a change which is even now only coming into ordinary use,—and the supports exhibited that combination of lightness and strength which has since been generally adopted for use in vessels of exceptional speed. These engines, built 35 years ago, are still in good order, and after constant use in four different vessels, built subsequently to the "Nautilus," were recently re-purchased by Mr. Thornycroft, as a record of early success.

The "small beginnings" of the now famous engine and torpedo boat works at Chiswick were made in 1864. Mr. Thornycroft was then 21 years of age, and began to build small launches on a piece of ground bought for him by his father opposite the bend of the Thames, so well known to University oarsmen as "Corney Reach," now more generally known in the annals of boat racing as "off Thornycroft's."

There he at once developed the principles of construction with which his early reputation was associated.



ENGINE OF THE YACHT "NAUTILUS," DESIGNED AND BUILT BY MR. THORNYCROFT WHEN 17 YEARS OLD. THE ENGINE IS STILL IN SERVICE.



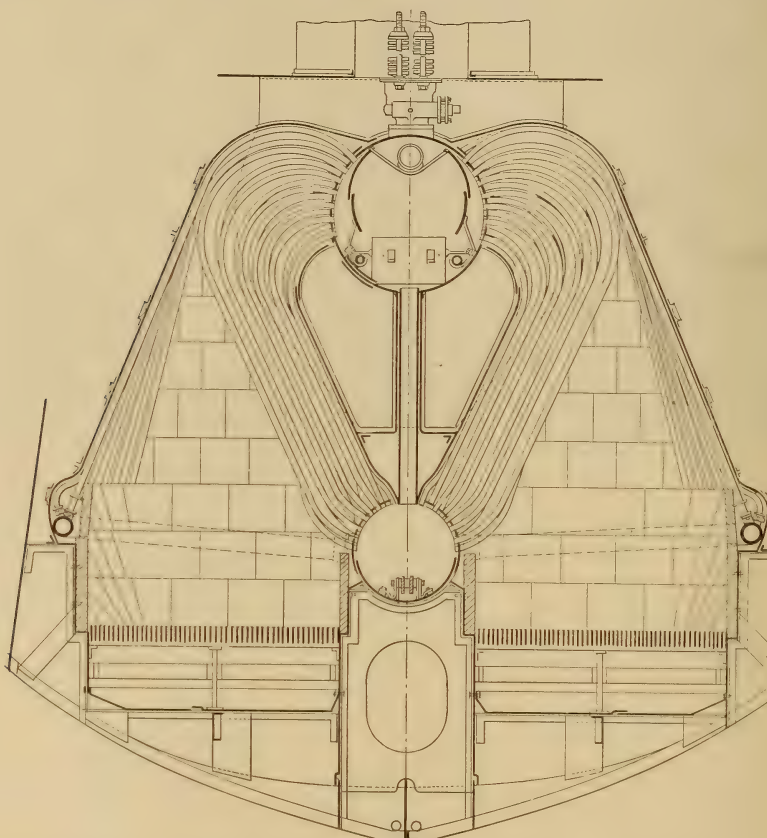
A STANDARD THORNYCROFT BOILER.

The "Ariel" and the "Slaney" launches were the fastest on the Thames. Then, voluntarily relinquishing constructive work for a time, he went North, and after gaining some experience of the methods of large shipbuilding firms in Wm. Palmer's yard at Jarrow, went to study engineering and mathematics in the best course then available,—that of the University of Glasgow. The time so occupied well illustrated the saying *Reculer pour mieux sauter*. The elasticity and freedom of choice in subjects offered by the Scotch University system were well suited to a mind which already knew in what direction it required instruction. Lord Kelvin, then Professor William Thompson, and the late Professor Rankine, were the University lecturers on natural philosophy and mathematics; Mr. Thornycroft completed the University course with credit and rapidity, and returned to his work at Chiswick, equipped with a fresh and enlarged mental purview for his subsequent career.

The soundness of the judgment which had decided on a temporary abandonment of what was already an established success in practical work, in order to secure the grasp or principle acquired from books, was quickly shown. Shortly after his return to Chiswick, Mr. Thornycroft launched the "Miranda." This vessel, though only 50 ft. long by 6 ft. 6 in. beam, attained the then incredible speed of 18½ miles per hour. She was fitted with a locomotive boiler. This type of boiler was then selected and adhered to by Mr. Thornycroft until the very success due to his own methods induced him to be the first to discard its use.

The performance of the "Miranda" was judged of such importance, that Sir Frederick, then Mr. Bramwell, accompanied by the present Lord Armstrong, went to Chiswick to witness its performance, and the former became its introducer to the world of mechanical engineering in a paper read before the Society of Naval Architects in March, 1872. After referring to the

interest of naval architects and engineers, which had been excited by the reports that had appeared in the newspapers of the performances of steam launches built by Mr. Thornycroft at Chiswick, Mr. Bramwell said:—"From these reports it appeared that steam launches, of about 50 feet in length, had attained speeds ranging from 17 to 19 statute miles per hour,—speeds which would be considered very good for the finest sea going steamers, and which have hitherto been regarded as impossible unless the vessels were at least 200 ft. in length." The trials were watched and checked by Mr. Bramwell, who had constructed a special indicator for measuring the speed of engines running at over 500 revolutions per minute,—a thing, "which so far as he had ever heard, no one had yet attempted." Mr. Bramwell concluded his paper by desiring that the thanks of the meeting might be accorded to Mr. Thornycroft for "a real step in the science of naval propulsion," and urging that the attention of naval architects should be directed to the subject of improving the speed of large steamers.



THORNYCROFT BOILER ON THE BRITISH TORPEDO BOAT DESTROYER "DARING."

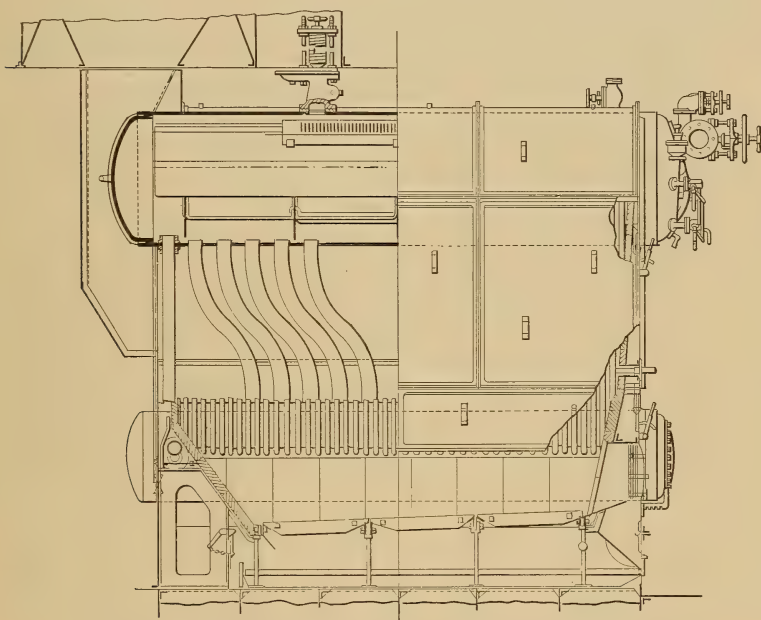
The "Miranda" established Mr. Thornycroft's reputation. His small yard at Chiswick grew into a large one; and the speed of his vessels rose by leaps and bounds. The "Gitana," for example, built for the Baroness Rothschild, to run on Lake of Geneva, made 23.9 statute miles an hour on her trial.

The "Gitana" marked the conclusion of a definite period in Mr. Thornycroft's career as an inventor. She embodied all the features which, for a time,—though for a time only,—satisfied him. She had the closed stokehold with forced draught, locomotive boilers, and engines as light and as strong as could then be made.

It was long before the speed of the "Gitana" was beaten or her principle of construction altered. The succeeding years were mainly devoted to the transference of these qualities to the torpedo-boat. This was an adroit use made of an opportunity,—another instance of combination, by which the new, fast boat was adopted and modified to carry a new weapon,—the locomotive torpedo. Mr. Thornycroft created a new industry, at the head of which he has always remained; his improved machinery was transferred by a natural process from torpedo boats to larger vessels, and in this way the torpedo boat has for some time been, in a measure, the "father of the ship."

Much scope was given also for minor improvements, such as the Thornycroft double rudders, and the screw turbines, made by the inventor for shallow draught vessels. The new boats acted as agents for the transmission of ideas for many years, and these ideas were mainly those embodied in the design of the "Gitana."

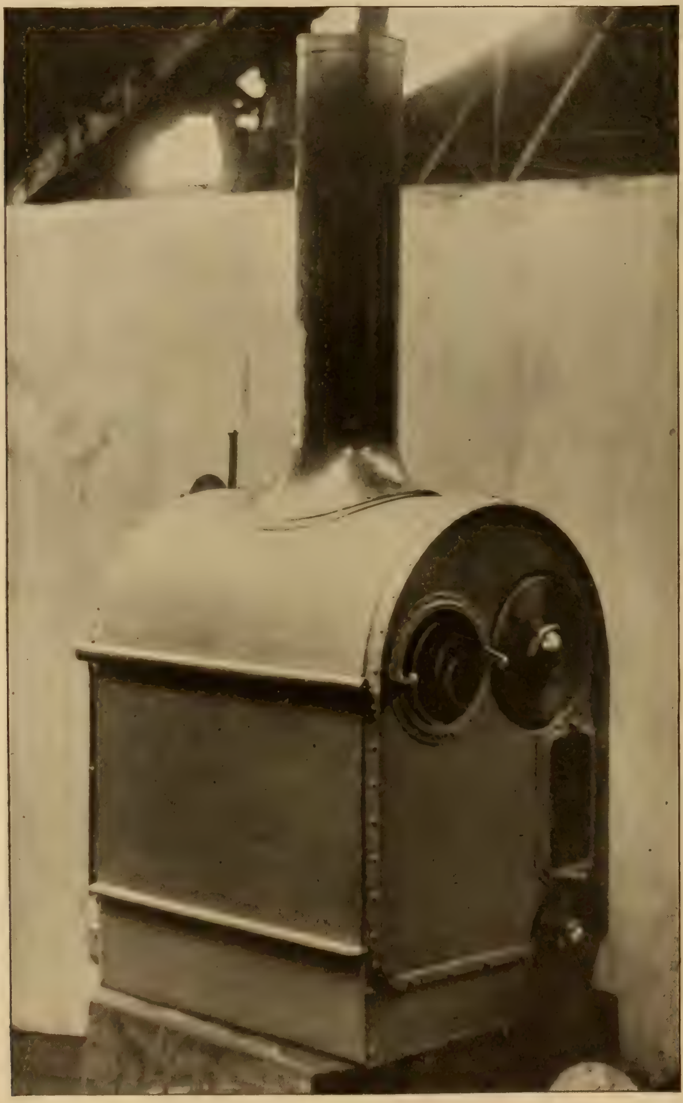
But with the speed of from 22 to 23 knots the limits of use of the locomotive boiler were already being reached; and though the rest of the world took some time to make this discovery, Mr. Thornycroft not only quickly realised the fact, but provided the remedy. More than ten years ago he designed and built what is now the famous Thornycroft water-tube boiler. This invention, and the author's consistent advocacy of the general principles which it represents, have, almost equally with the production of the first fast steam launches, commanded the increasing respect and attention of engineers all the world over. Although the water-tube type of boiler has been tried since



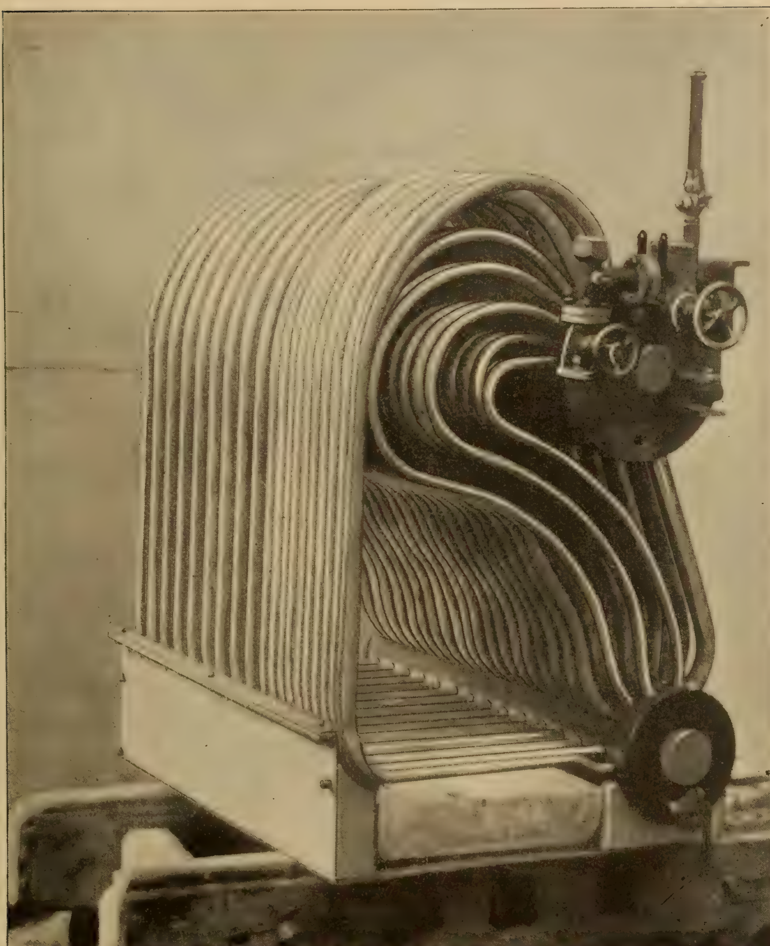
ELEVATION AND PARTIAL SECTION OF THORNYCROFT BOILER ON THE BRITISH TORPEDO BOAT DESTROYER "DARING."

the first introduction of the steam engine, it is only recently that it has been made a safer and better boiler for its special purposes, than any other type ; and the credit of this is largely due to Mr. Thornycroft.

When he first described the conditions for its successful working, he showed how it was necessary to have the tubes of small diameter, in order to make them safe, and able to stand hard work, and how the boiler itself must be designed so as to give to the flow of water in the tubes, and to the hot gases outside them, definite and systematic courses, and further, that this could be done only by working in conformity with certain physical laws. These views, taken theoretically, were in some respect not new. But Mr. Thornycroft



A THORNYCROFT LAUNCH BOILER.



A THORNYCROFT LAUNCH BOILER WITHOUT ITS CASING.

embodied them in practice and made a boiler at once scientific and perfect for manufacture. It would give a pressure of steam up to 250 lbs. per square inch in twenty minutes after lighting the fires; it weighed, with water and fittings, 33 per cent. less than the locomotive boiler, developing equal power; its tubes never leaked, and it was so suited for use with forced draught that no precaution had to be used in applying or discontinuing this valuable auxiliary to speed.

The invention came before the world at a critical time in the history of modern naval engineering. The limit of the older forms of boiler had been reached. Tried in light vessels from which high speed was desired, they were a failure. Meanwhile the speed of the torpedo boats, fitted with the Thornycroft boiler, was rising fast. The "Coureur" did 24 knots; the "Ariete" 26 knots. The Danish Admiralty put the new boilers into large cruisers, with marked success, and the English Admiralty resolved to try them in the "Speedy," one of the "sharpshooter" class of torpedo gun-boat,—a vessel of 800 tons. The trials were watched with the greatest interest and were fully reported. The "Speedy's" boilers

H. M. S. "BOXER" RUNNING AT 23 KNOTS WITH THORNYCROFT BOILERS. HER HIGHEST SPEED IS OVER 29 KNOTS.

gave her 1000 H. P. more than was given by the locomotive boilers in any vessel of her class. They have since undergone every form of trial and experiment, and the ship has been continuously in commission since 1892, without losing either in speed or in the efficiency of her boilers.

Lord George Hamilton was First Lord of the Admiralty when this important step was taken. In reference to its occasion and results we quote the following from a speech recently made by him at the Royal United Service Institution:—"A great alteration has recently taken place in the Navy, and Her Majesty's ships are, in future, to be boilered with water-tube boilers. Mr. Thornycroft has the merit of being the first to supply these boilers to the Navy. The first vessel so supplied was the "Speedy," and it was the very satisfactory performance of that vessel which induced the Admiralty to adopt the system on a large scale."

The most marked feature of this change is the almost exclusive employment of water-tube boilers in the new torpedo boat destroyers of from 26 to 30 knots. They represent the latest results accruing from the change of boiler. In those built by Mr. Thornycroft, boat after boat successively beat the record of speed of the world, and that of its sister vessel previously launched from the same yard. The steam was supplied by three boilers only, while other vessels of the same class, also using water-tube boilers of different design, were fitted with as many as eight. The trials of the 30-knot boats, now building at Chiswick, will probably afford as complete a vindication of the new principle as has yet been offered.

Meantime it is understood that Mr. Thornycroft is seriously considering the need for lightening the strain on the men who have to work these highly concentrated machines. He has already invented an automatic feed gear to supply the boilers with water, in place of leaving this to the engine-room staff; and this is being extensively fitted to the new ships.

In concluding this notice, we are entitled to ask, what is the distinguishing character, if any, of Mr. Thornycroft's contributions to mechanical invention, and, also, what further contributions to engineering progress may reasonably be anticipated from the same source? In answer to the first, we should be inclined to say that Mr. Thornycroft's work in all new directions has for a common and constant characteristic, completeness and finality. When he has introduced a new invention it retains nothing tentative or half thought-out, nothing left for pruning or addition. In proof, we need only cite the Thornycroft boiler. The idea of a water-tube boiler was nothing new; but it was a discredited idea. Another type held the field in every department. Water-tube boilers had been tried and failed. It was admitted that if a water-tube boiler with perfect circulation could be made, then its lightness, economy and suitability for forced draught would make it a desirable substitute for the existing type.

Large down-tubes and small up-tubes, curvature of the tubes, and other features of the Thornycroft boiler had been tried piecemeal by this and that inventor who had yet failed. What Mr. Thornycroft did was to combine all the requisite factors and produce a complete success. Such work is the common characteristic of uncommon ability. Since the boiler was first made it has not been altered in a single detail of principle, though when first introduced to the notice of the profession it was criticised with more than common scrutiny, and the correctness of its principles, now accepted as part of the recognized stock of mechanical knowledge, was only reluctantly owned. This must always be the attitude of responsible persons in regard to inventors who are ahead of the times. But their hesitation was, in this case, an error in judgment.

The completeness of the design has been born out, not less by the host of subsequent water-tube boilers now being produced on the same general principles, but by the fact that any devi-

ation from the Thornycroft design has been, so far, a retrograde step. Straight tubes have been substituted for curved tubes, "drowned" tubes for those delivering above water, large up-tubes for small up-tubes, with the inevitable result, sometimes, of minor, sometimes of larger, diminutions of efficiency. The concrete instance to hand will probably be found when the report of the respective performances of the various water-tube boilers, of which the English Admiralty wisely made trial in the new torpedo-boat destroyers, is published.

Time must elapse before the final judgment as to durability, as well as success in trials, is pronounced. But to those who have followed the results of the latter with care, and the subsequent history of the vessels, the results of comparative "deviation from type," are very instructive. As to the immediate future, apart from the question of propelling machinery, it will not be amiss to note the progress so far made by Mr. Thornycroft in the direction of steadying the roll of ships. His work in this department was briefly noticed in a paper read before the British Institution of Naval Architects in April, 1892. Mr. Thornycroft bought the steam yacht "Cecile," of 280 tons, and fitted it with a moveable weight, controlled by a mechanism which was, in turn, regulated in accordance with the movements of a pendulum.

This pendulum gave instant notice of the impulse of a wave against the ship's side. The apparatus was described by Mr. Beauchamp Tower as one of the most beautiful pieces of mechanism he ever saw. "It is really an intellectual treat for anyone who can appreciate mechanical ingenuity. It is carrying out what to many mechanicians is a dream—the possibility of making a small force call up and control a giant force, the giant force being perfectly docile to the small force. It is like making a mouse lead an elephant. The slightest motion of the mouse, and the elephant immediately follows." The practical success which lay behind this modest and somewhat academic address was then explained in a speech made by Sir William White, the talented chief constructor of the British Navy. We quote his words *verbatim:* "By the courtesy of Mr. Thornycroft, I have had the opportunity of taking a trip to sea in the "Cecile" to look for bad weather and observe the working of this apparatus. I feel bound to say a word or two on what I then saw. It is unnecessary for me to emphasize the impression of the wonderful ingenuity and practical success of this apparatus, which was tried in this yacht under very adverse conditions. The yacht was very "stiff," with a metacentric height of about 4½ feet and a very short period. Both of these circumstances tell against the gear. Yet, by my own observation, I can certify to the fact that the movement of a relatively small weight did destroy half the rolling . . . . We all know that Mr. Thornycroft, in speaking of his own work, is always modest. In this particular instance he has, I think, excelled himself. It is very easy to speak of controlling the gear of a hydraulic ram by the movement of a small pendulum, which follows the movement of a quick rolling yacht. But it is quite another thing to secure that control . . . . and I am confident that the beautiful, almost automatic, and, I may say, intelligent movement one sees in this gear, are capable of a very wide application. Whatever the controlling gear was called upon to do by the waves outside the vessel it did, neither more nor less. The time may come," added Sir William White, "when we shall see rival passenger ships crossing the Atlantic, some controlled by Mr. Thornycroft's gear, others fitted with cots, chairs and tables, carried by Mr. Tower's steadying apparatus."

Current Topics.

WHEN locomotives were first built, and began to trundle their small loads up and down the newly and rudely constructed railways of England, the public roads were, for the greater part, crossed at grade, and the engine driver had no way of giving warning of his approach except by blowing a tin horn. But this, as may be imagined, was far from being a sufficient warning. One day, in the year 1833, so runs a story of the origin of the locomotive whistle, a farmer of Thornton was crossing the railway track on one of the country roads with a great load of eggs and butter. Just as he came out upon the track a train approached. The engine man blew his tin horn lustily, but the farmer did not hear it. Eighty dozens of eggs and fifty pounds of butter were smashed into an indistinguishable, unpleasant mass, and mingled with the kindling wood to which the wagon was reduced. The railway company had to pay the farmer the value of his fifty pounds of butter, his 960 eggs, his horse, and his wagon. It was regarded as a very serious matter, and straightway a director of the company went to Atton Grange, where George Stephenson lived, to see if he could not invent something that would give a warning more likely to be heard. Stephenson went to work, and the next day had a contrivance which, when attached to the engine boiler, and the steam turned on, gave out a shrill, discordant sound. The railway directors, greatly delighted, ordered similar contrivances to be attached to all the locomotives, and from that day to this the voice of the locomotive whistle has never been silent.

THE latent power of a maritime country lies in the private ship yards and engineering works at large within her borders. In this respect Great Britain probably still stands unrivalled. In the old wars, in the days of oak and hemp, England's yards enabled her to launch ship after ship ; some, it is true, were not exactly "Hearts of oak," for when oak ran short, and time pressed, shift had to be made with less staunch material. Again, the many iron foundries enabled cannon to be cast throughout the land, and the power was not wanting to bore and finish them. Thus, by her recuperative power, England maintained her mastery of the sea. But in old days of sails, when it took perhaps 12 months to get around the world, wars were reckoned by as many

years as now they would by months. The battle ship has become so infinitely more intricate, such a vast and highly organised machine, that its construction cannot be hastened as of old. Therefore, so far as the main body of the fleet is concerned,—in spite of the wonderful acceleration in dockyard construction of late,—as a nation finds itself when war breaks out, so must it fight it out. This, however, does not apply to the smaller craft, the auxiliaries of the fleet which are expected to perform so large a share in the work of destruction. Here the latent power will be made sensible.

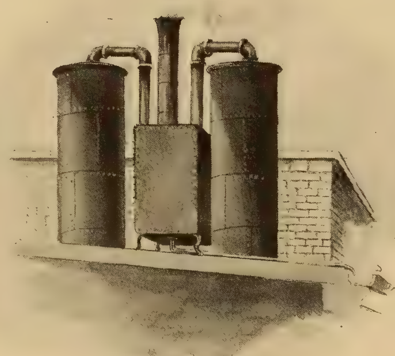
A foretaste of what may be accomplished has lately been given by Messrs. J. &. G. Thomson, at the Clydebank yard, where the "Paris," 'New York" and many other renowned liners have been built, to say nothing of the "Terrible," the first of the two largest cruisers ever constructed in England. Some time ago the Spanish Government awoke all at once to the immediate necessity of quashing the Cuban insurrection, and, finding that they wanted light, quick vessels, searched the yards of Europe, only to learn that the market had been cleared by the South American republics in the settlement of their little differences. There being nothing available "in stock," proposals were invited for quick dispatch, and Clydebank undertook seven gun-boats, to be turned out in three months, heavy penalties being recoverable for further delay. The contract was signed on July 11, 1895, but owing to Glasgow Fair holidays, which no Clyde artisan will miss, especially if his firm is exceptionally busy, a commencement was not made until July 22. The first vessel was launched on August 24, and was ready to be taken over on September 11. Others followed in quick succession, the last being completed ten days within the contract time, the entire period occupied for completing the seven vessels being just ten weeks,—a little less than a vessel a week. The displacements of the vessels vary between 100 and 300 tons, and the speeds, from 12 to 13 knots. The first vessel was 136 feet long, 26 feet wide and 11 feet draught. A yard that can turn out work in this fashion, in spite of having a big cruiser, a battle ship and three torpedo boat destroyers in hand is, indeed, a source of strength to its country.

Another piece of smart work was executed by Messrs. Yarrow & Co. in turning out the stern wheel gun-boats "Mosquito" and "Herald" for service in African rivers in the British service. England then had a little trouble looming up with Portugal. The order was given on the first day of April, and on the fifth of May following the trial trip took place, the construction having occupied just 25 working days. In the year 1893 the French Government found it necessary to give the Dahomeyans a lesson in a hurry. Wanting a shallow-draught gun boat for the purpose, they naturally first tried their own native builders, but no Frenchman would undertake to turn out a vessel under four months, some asking ten. They then applied to Messrs. Yarrow & Co., who considered that the thing could be done in a month. They booked the order, commenced work on April 28, and in twenty-three working days, or by May 23, the boat had made her trial. This vessel was 100 feet long by 18 feet wide, and, like the two built for England, was made in portable sections which could be carried on a steamer and put together afloat. She steamed 10 miles an hour and carried 100 troops.

While English and American engineers are vigourously agitating the matter of utilising the enormous accumulations of culm or slack in their respective coal regions, either by directly burning the stuff under steam boilers with suitably designed grates and other furnace accessories, or by gasifying it and using the product for driving gas engines on a large scale, German engineers are

quietly working in much the same field and with equally, if not more, satisfactory results. In the vicinity of Bitterfeld, for example, in the Elbe district, there are almost immeasurable surface deposits of bituminous coal, so low in heating value that the simple cost of transportation would become prohibitory to its use at any much removed place. Right at Bitterfeld, however, the coal has been shown to be the cheapest fuel to be had in Germany, and accordingly the Elektrochemische Werke were installed there a little over a year ago by the Allgemeine Elektricitäts-Gesellschaft, of Berlin, the largest European electrical company. The Elektrochemische Werke have a 2000 horse-power plant; they produce mainly chlorine and caustic potash on the process of Dr. Rathenau, the just-mentioned bituminous coal being used exclusively in their operations, and with such good results that an extension of the plant to 3000 horse-power capacity is now under way. The works are the first in Germany to electrically produce also calcium carbide, sodium and other refractory metals on a large scale. Right in the line of electro-chemical work, it is interesting to note that a number of other similar installations have been erected, or are under consideration, by the Allgemeine Company, —one at Rheinfelden, where the river Rhine is called upon for 28,000 horse-power; another in Italy and in Switzerland; and still another in Russia. England and the United States also are being looked to by the great Berlin Company as promising fields for their enterprise.

HEADS for steam exhaust pipes from engines, projecting above the roofs of buildings and designed to prevent the fall of spray from such pipes, have been brought out in numbers and almost every maker of steam specialties has put one on the market. In almost every case, too, do they perform their tasks fairly well, and yet a simple "home-made" piece of apparatus, like that shown in the annexed sketch, and which every factory owner can turn out for himself, will do the same work. The one here shown was put up a number of years ago on a well-known tall office building, and consists of nothing more than a rectangular tank, about six feet deep and three feet square, into which the several exhaust pipes from different engines are carried. From the top of the tank a free escape pipe leads to the outer air. This pipe is somewhat larger than the separate exhaust pipes and extends about half-way down into the tank. A small drip pipe carries away the water of condensation from the bottom of the tank to the eavestrough. There are no deflecting plates and no complicated sheet metal work.



A SIMPLE EXHAUST PIPE HEAD.

A STRIKING example of the manner in which the trades unions interfere with the action of workmen and so add to the expenses and cripple the operations of trade is afforded by a strike that was in force a short time ago at Liverpool. The men employed in loading two steamers were stopped working by the union delegates on the ground that whereas, according to union rules, only four bags of goods could be placed in the slings, they were putting in five

bales. Now, as the cranes by which these steamers were being loaded were worked by steam, there was no question of men being called upon to labour beyond their strength. The rule would therefore appear to be simply a device to prolong by one-fourth the operation of loading, thus adding twenty-five per cent. to the labour cost. It is, in fact, neither more nor less than a tax upon employers of five shillings in the pound, for the benefit of the members of the union. To the general public, ignorant of the manner in which most of the unions restrain members from working up to anything like their real power, it would seem incredible that such a restriction should be imposed in regard to steam cranes. The same principle, however, handicaps employers in almost every branch of trade. Colliers are forbidden to fill more than a certain number of corves a day, bricklayers may not lay beyond a prescribed number of bricks, less than half that which a good workman would lay. So it is in other branches of labour ; but it must be acknowledged that the attempt of the labourers in the Liverpool docks to restrict even steam power, is, perhaps, the most outrageous one yet made to augment the cost of labour.

WITH the use of higher and higher steam pressures, and the consequent growing adoption of water-tube boilers, particular interest is attached to an account, recently given by Albert Durstan, engineer-in-chief of the British Navy, in his presidential address before the British Institution of Marine Engineers, of some experiments, made by the British Navy Department, to ascertain the steam pressure required to actually burst sound boiler tubes of small diameter. A copper tube, 1 inch external diameter, and 15 B. W. G.—0.070 inches—in thickness, was taken from a boiler of a torpedo boat destroyer that had been steamed under forced draft, at the full power, to a large extent, partly filled with water and the ends closed. It was placed on a smith's forge, inclined at an angle of about 20 degrees to the horizontal and a pressure gauge was fitted at the upper end. On being heated, the pressure rose to 200 pounds and the blast was applied. The pressure rapidly increased to about 1500 pounds, then rose to about 2000 pounds, the tube bursting six and a half minutes after pressure was first shown on the gauge. The bursting pressure was not definitely noted, as the limit of the pressure gauge was exceeded, but, as far as could be judged, only to a slight extent. The tube had apparently burst at the bottom next the fire ; but the whole portion that was subjected to heat was split open and practically flattened. Taking the bursting pressure at 2000 pounds, this would correspond to a stress of about 14,700 pounds, or 6.55 tons per square inch. By calculation, the temperature of the steam would probably be about 640 degrees F.

A SIMILAR experiment was made with a new steel tube intended for a torpedo boat destroyer boiler. This tube was 1¼ inches external diameter, and 12 L. S. G.—0.104 inch—thick, and had been coiled cold into a spiral of about 6 inches diameter. This tube, which was half filled with water, burst at a pressure of 4788 pounds per square inch, the tube in this case separating and only flattening out locally. This pressure corresponds to a stress of about 26,800 pounds, or 12.85 tons, per square inch. The temperature of steam in this instance would probably be about 800 degrees F. Although it was endeavoured to approach the circumstances of actual working, it must be borne in mind that in these experiments the tubes were partially filled with water and only slightly inclined to the horizontal, whereas in water tube boilers, where such small tubes are used, the tubes are generally more nearly inclined to the vertical, and in all cases there is a stream of water, or water and steam, passing through the tubes when generating steam.

ANENT the matter of bulged boiler-plates, traceable to the use of oil in

boilers for loosening scale, it is worth noting that several years ago Professor V. B. Lewis made a very suggestive set of experiments, designed to show how thoroughly non-conductive a coating may be produced by the mixture of oil and dirt, or incrustating material, such as is apt to, and does, go on within a boiler. It is well known, and has previously been pointed out in these pages, that when oil is put into a boiler, it remains on top of the water only until it comes in contact with small particles of dirt. As soon as such contact takes place, the two materials combine, mechanically, into one of about the same specific gravity as that of the water, and this mixture will ultimately find its way to the heating surfaces, where it will stick and cause overheating of the plates. A very thin deposit of this kind—so thin and inconspicuous, sometimes, as to completely escape detection—will do a remarkable amount of mischief. All this is now pretty well known, but it remained for Professor Lewis to show just how thin such a coating of oil and dirt might be and yet retain its very objectionable property of preventing ready transmission of heat from one side of a furnace plate to the water on the other side.

As detailed before the British Institution of Naval Architects at the time, Professor Lewis' experiments consisted in taking clean iron vessels and coating some of them on the inside, with a layer of the deposit one-sixteenth of an inch thick. Water was put in the clean and coated vessels and raised to the boiling point over a coal fire, and while the water was boiling the fire was suddenly removed and substances whose melting points were known were pressed against the outside of the vessels. As a result he found that the clean iron vessel did not melt sulphur, and that consequently its temperature on the outer surface was below 239 deg. F. The coated vessel melted the sulphur, but did not ignite it, though it ignited gun cotton, so that its temperature was above 392, but below 482 deg. F. It was evident that the fire was by no means as severe as in boiler practice, and the experiments were repeated with an atmospheric blow-pipe flame with the result that the clean vessel had a temperature under 239 deg. F., while the coated vessel was so hot on its outer surface that it melted zinc, thereby indicating more than 793 deg. F. These figures tell a story which every one who is using, or who may be contemplating the use of, oil in boilers, will do well to bear in mind. The oil will serve an excellent purpose, with judicious management and careful watching; without them quite the reverse may prove itself true.

FACTORY owners whose fire protection system involves the use of steam fire pumps, controlled by any one of the several makers of pump governours, ought to find something of interest in a recent statement made by Mr. John R. Freeman, the chief of the bureau of inspections of the Boston Manufacturers' Mutual Fire Insurance Company. Says Mr. Freeman:—"Pump governours, so called, are designed to maintain a constant water pressure in the pipe system to which the pump delivers, by opening the steam throttle valve to the pump whenever the water pressure falls below a certain point, and, conversely, to shut the steam throttle valve whenever the pressure rises above the said point. Nearly all of them perform their work fairly well when new, and the most of them will afford satisfactory means for controlling pumps for elevator service or for manufacturing operations. Several years ago there was a tendency to introduce them frequently in connection with fire service where there was no public water supply to furnish pressure to the automatic sprinkler system or where the mill walls were not suitable to support the weight of from 20 to 40 tons presented by a 5000 or 10,000 gallon tank. The Factory Mutuals have never looked on these with favour except as a last resort, and the experience obtained from year to year has led them to be looked on with even less

favour, until now they are never accepted for controlling the primary supply to automatic sprinklers. Our inspectors have, in very many instances, found them incapable of operating in a proper manner after they had been in use for a year or more. In some cases they got stuck and would not respond automatically to the call for water. In other cases the valve stem becomes corroded so they can open only to a small degree, and while maintaining the pressure as shown by the gauge under slight draft satisfactorily, cannot open wide enough to respond to a heavy draft of water. In many cases it is found that to thus control a fire pump wastes steam besides subjecting the pump to unnecessary wear"

"A NEW source of danger has just been revealed by an experience at a factory insured by certain of the Factory Mutuals. In this case the pump drafted its supply from a very large cistern. By the accidental leaving open of a valve on the discharge pipe by some workmen, the governour kept the pump in operation during the night until this cistern was emptied to a point which admitted air to the suction pipe, so that the pump lost its suction. The water pressure, of course, instantly disappeared, and this caused the pump governour to force the steam throttle valve of the pump wide open, and this running the empty pump under a full head of steam quickly tore the pump to pieces, breaking it so badly as to render it worthless."

THE "sand track" for derailing switches and for stopping runaway cars,—an invention of Professor C. Köpcke, of Dresden, Germany,—is used in several places on the Saxon State railroad, and with very satisfactory results. The arrangement consists in the use of two rails to which the derailing switch leads, and which are buried in sand. Neither one of these rails crosses the main line rails, but they are of considerably lower section, so that the sand with which they are covered is flush with the top of the main rails. The sand has been used of different depths, from 2 in. up to 5 in. The idea is simply that the wheels should be stopped by running in this bed of sand. It has been found by experiment that the retardation is gradual, without any jerk, and without any tendency to lift an empty car placed between two loaded ones. The resistance of the sand diminishes with the length of the train, the first wheels finding more resistance than those which follow; but after the repeated passing of wheels there is still a good deal of retarding effect from the sand. The resistance seems to increase with the velocity and to a small degree with the thickness of the sand layer.

BEFORE a great while steam fog-signaling machinery will probably have become obsolete in the United States, and compressed air apparatus, with which satisfactory experimental results have latterly been achieved, will take its place. Trials were made a few months ago at the Staten Island lighthouse station, near New York, and also on board one of the lightships off the New Jersey coast, with Hornsby-Akroyd oil engines driving air compressing machinery for working the fog horns there, and it would seem, from all accounts, that these installations have proved themselves all that was expected. The greatest advantage, perhaps, which a compressed air fog horn outfit offers, is the quickness with which the sound can be made. Under the old method it took from 45 to 60 minutes to light the fires under the boilers for the generation of the steam to blow the horns. The lighthouse keeper, as soon as he saw the fog coming, lighted his fire and prepared to get a full head of steam on. This he was obliged to do several minutes before the fog closed down. Sometimes it came rapidly and surrounded him long before he could get the signals working. Now, in 5 minutes air can be compressed in the tank, and a blast of

maximum force can be given immediately. The tank is left full of compressed air after it is used, and contains enough to keep the horn going for 10 minutes. The horns can be started before the fog rolls down upon the keeper and kept blowing steadily until the fog lifts. The power can readily be shut off during any temporary lifting of the fog, while formerly it was necessary to keep the fires up for a long time so as to be sure of being in readiness should the fog roll down again.

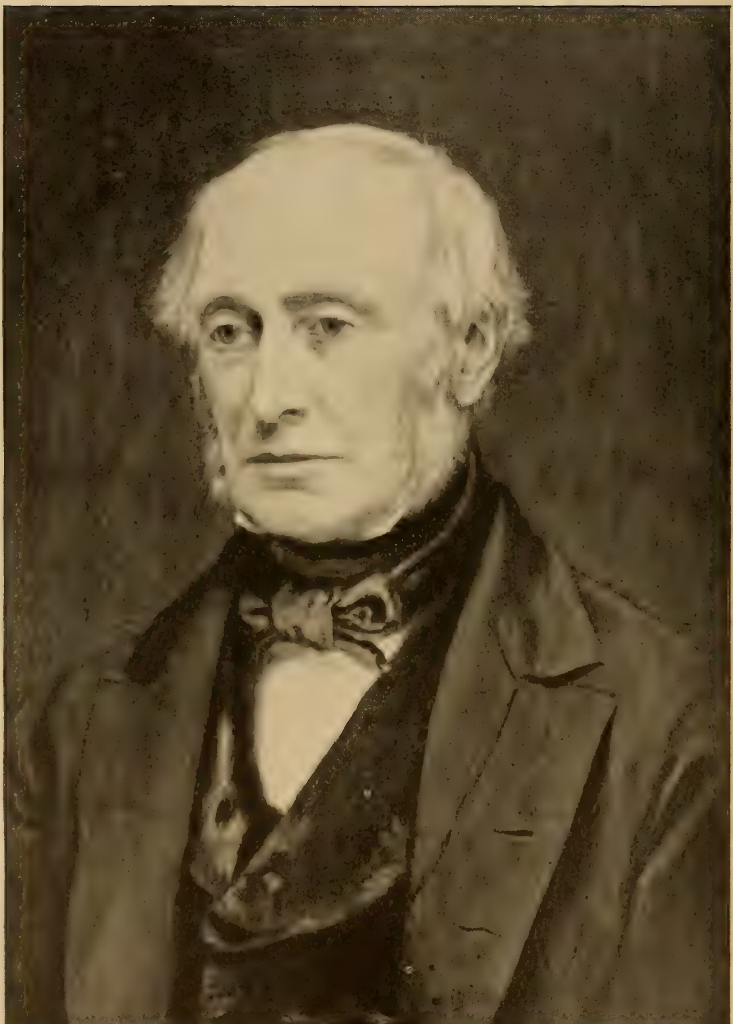
REGARDING the working of men in submarine caissons and in foundations generally, where heavy air pressures must be employed, it is interesting to note the experiments which have recently been made by M. Hersent, a French engineer, to determine the physiological effects produced by more or less heavy pressures and by the rapidity with which they are let on or off. M. Hersent experimented at first on dogs, and afterwards with men. With the former, in four of the experiments the dogs were exposed to a pressure of 50 lbs. per square inch, which was then reduced to atmospheric pressure in less than a minute. Two of the dogs died from the effects of the sudden release of pressure. In 21 other experiments, made with air at 80 lbs. pressure, the reduction being made in one hour, three dogs died. One of these died in a case in which the temperature of the lock was allowed to fall, whilst the second had already passed through the four previous experiments in which the release of pressure had been practically instantaneous. The third victim was in an unsatisfactory physical condition at the time of the experiments. Experiments with cats, frogs and mice showed that these animals did not appear to be injured even when the release was instantaneous.

FIVE experiments were then made with men. In the first, the air pressure was raised in 15 minutes up to 45 lbs. per square inch, under which the men remained one hour, and the release of pressure was then effected in 50 minutes more. One of the men had afterwards an attack of colic, but this is believed to have been due to other causes than his compressed air experiences. Five trials were then made with the two remaining men, the pressure being raised to 65 lbs. per square inch in half an hour. As before, the men remained under this pressure for one hour, the release being finally effected in 1 hour and 40 minutes. The temperature of the lock was kept up in this case by means of a steam coil. The men complained of itching on the skin, and one of them had pains in the limbs which lasted three days. The remaining man then underwent three further tests, in which the pressure was raised to 77 lbs. in three-quarters of an hour. As before, he remained one hour under this pressure, which was then gradually reduced to atmospheric pressure in three hours more. The man complained of slight pricking sensations, which, however, readily yielded to treatment. M. Hersent's conclusions, of course, are much like those which every engineer, experienced in compressed air work, has formed for himself, namely that by taking certain precautions, particularly by increasing the time allowed for passing through the air lock, and by warming the air there, when men are coming out, evil effects can be avoided to a great extent. M. Hersent thinks that with such precautions depths of 160 feet under water can be reached with as little risk as those of 80 feet have been in the past. When pressures of 50 lbs. are reached, an hour should be taken in passing through the lock, and for one of 78 lbs. per square inch three hours are not too much.

SPEAKING of the machine tools at the venerable Soho Foundry, in Birmingham, England, with which both James Watt and Matthew Boulton were prominently identified in their time, the *Engineer*, of London, says:—"The tools are in certain respects unique.

They form part and parcel of the place. They have been made where they stand. They are an integral part of the premises. We do not say that they could not be moved ; we do not say that they were made without any idea that they would ever have to be moved. At every turn, too, we meet with devices which have been brought out time and again as new, and we feel that master minds have been at work—the minds of men who thought very clearly, who knew exactly what they wanted to do, and then did it in the best manner ; and all the while we note that the influence of the millwright made itself felt, and that things were done as mechanical engineers would not do them now, but as they could have been done in Murdoch's day, or not done at all. There are square threaded screws, for example, two inches in diameter, ten or a dozen feet long, four threads to the inch, and these have all been cut with hammer and chisel ! What would the average modern fitter think if he was asked to undertake such a job ? One of the foremen who has been for more than thirty years at the works told us that he very well remembers seeing some of the old hands cut screws with a chisel, and he was an apprentice when himself taught the art. The bar was supported in a triangular wooden trough, and the screw cut bit by bit to a template. It is easy to see that under these conditions screws would be used sparingly, at first at all events.

"In the principal machine shop, one end of which is used as an erecting shop, are two very heavy vertical planing machines. The frames are secured to the wall by stout braces, and the carriage holding the tool travels. The work to be planed is secured on a table at the ground level, and the planing is done on the side next the wall. The system was adopted because very heavy castings were made and had to be handled,—castings weighing as much as nine or ten tons, and in later years as much as twenty-five tons, as, for example, the oscillating cylinders of the Irish channel mail boats. There were no planing machines that would carry such a load, and even if there were, it was held to be much more economical of power to drive the tool along the work than to drive the work under the tool ; and in the present day it is beginning to be found out that the moving tool is more economical than the moving casting. The principle has long been employed in plate edge planing machines."



AFTER A PAINTING BY MRS. S. E. WALLER.

LORD ARMSTRONG, C. B.

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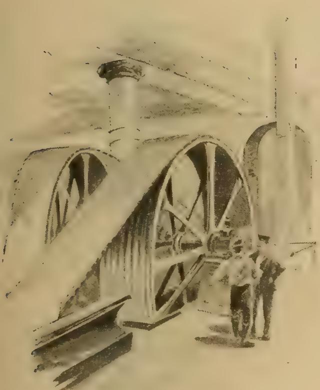
THE DEVELOPMENT OF ELECTRIC POWER STATIONS.

By C. J. Field.

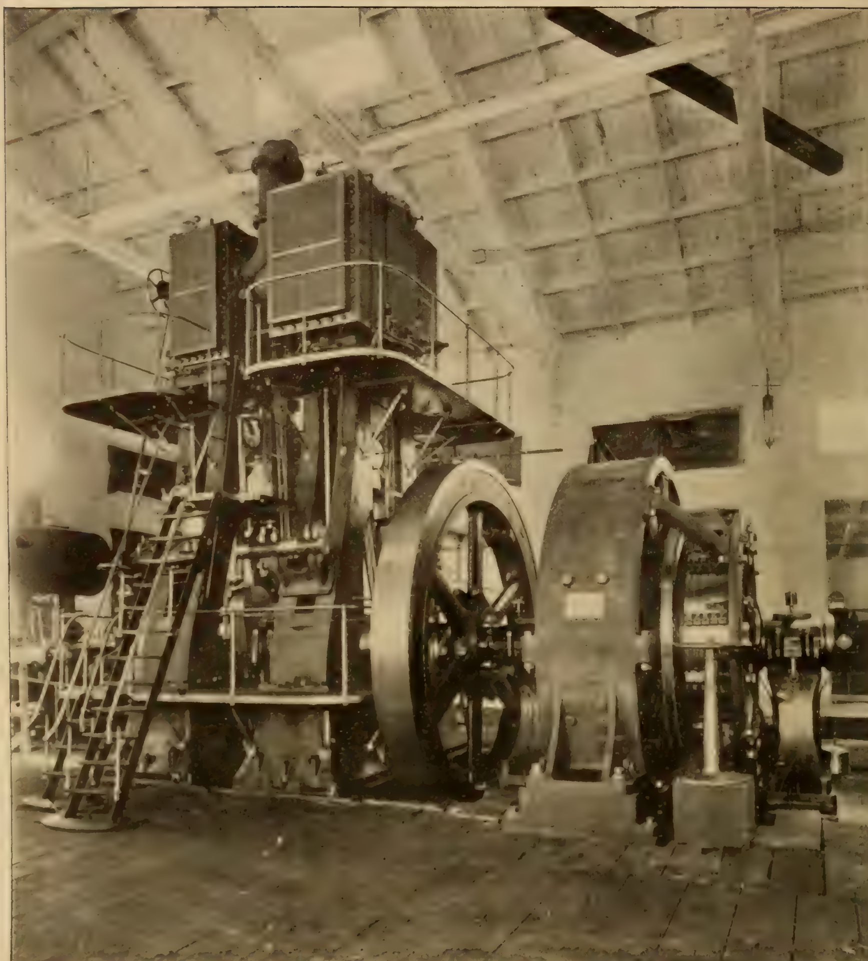


DURING the past few years there has been a very marked improvement in the construction and in the economy of operation of electric power stations. Up to 1889 and 1890 by far the larger number of stations were operated by small units, and 100 to 150 kilowatts were about the limit of the size of generators which were built and operated. The type of generator was, as a rule, the old bi-polar for direct-current work, and on constant-current arc-light machines, fifty-light machines were about the limit of capacity. Alternating work has only just begun to be developed.

We have seen during the past few years a growth and development that has been startling, not only from the electrical, but also from the steam end. The steam plant up to that time was, in the majority of cases, installed without any regard to its economy or adaptability of operation on varying loads. Either small high-speed engines, direct belted to generators, or large Corliss engines belted to main and counter-shafting, and from there to generators, were the general practice.

The result in either case was not an economical showing as to the electrical output per pound of coal. In any case, the cost of repairs and maintenance was a very high percentage of the operating expenses. Electric companies had not begun to appreciate the desirability of steady loads to reduce their operating expenses, nor the fact that a doubling of the load did not mean a doubling of operating expenses. Many of the companies were going along just on the border line between gain and loss, and getting results which were not satisfactory or encouraging to stockholders, whereas with more energy and an increased investment they would have shown a profit.

About the time indicated, a marked change began. Companies appreciated more the advantage of good engineering, and more engineers were in the field that were making a specialty of this work. The steam engines, too, were improved in every respect. The high-speed or automatic engine has been developed so as to give good satisfactory economy, with a single valve, up to about 300 H. P. Corliss engines



A MODERN DIRECT-CONNECTED 1250 H. P. UNIT.

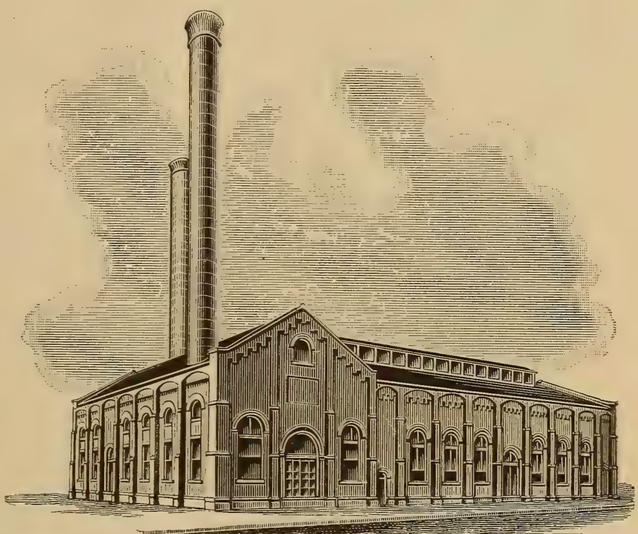
have been improved in their general construction and regulation to give satisfactory results and also have been built to operate at a higher rotative speed in order to enable them to be used with direct connection.

An intermediate field has been developed with the marine type of vertical engine, combining many of the advantages of the high-speed or automatic variety in regulation and general economy, with that of the Corliss in high efficiency. For large power plants there is no doubt but that the vertical type of engine, either in an automatic, marine or Corliss type, is best adapted to the average conditions both as to economy in general service and economy in floor space and operation. All ot these types of engines are now coupled direct to the generators, which are operated at the same speed as the engine.

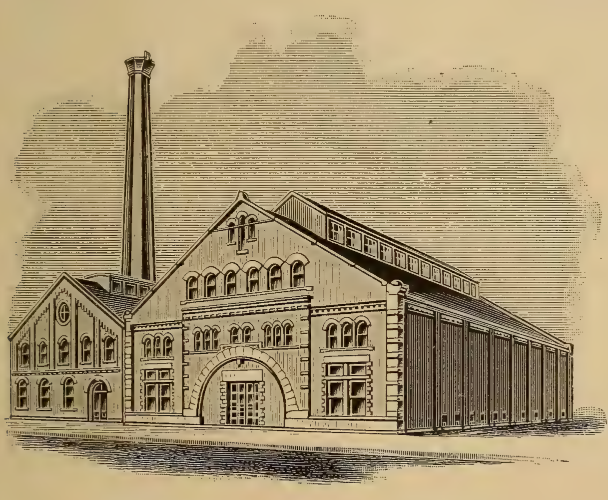
The boilers, as forming one of the main and important parts of the power plant, have been much improved in their construction and detail, and to-day, with the higher steam pressure in a large station, one of the many well-known types of water tube boilers is almost universally used. Proper handling of these boilers, and automatic

feeding systems, automatic handling of coal and ashes, and weighing thereof, are introduced in many of the best stations and serve to give them definite results and data in daily service.

The generators themselves have been developed so that now they are built for any capacity which is required under service demanded, up to 5000 H. P. units. Many of the types of machines in direct-current work, especially for light and power purposes, are built with what is known as the iron-clad type, or slotted, armature, which is especially economical in its decreased repairs, and the ease with which such repairs can be made when required. This type of machine is universally made of the multipolar form, either with the fields inside or outside. In the general type the fields are outside, or at the sides of the armature.



TYPICAL AMERICAN POWER STATIONS.—THE NEWARK, N. J., ELECTRIC RAILWAY STATION.



THE BUFFALO, N. Y., RAILWAY CO.'S STATION.

In one or two special cases, the armature revolves over the fields. In low-tension work, the commutator bars are part of the armature coils, thereby increasing the simplicity of the machine. For railway work, this type of machine has been built up to 1500 K. W., and, for central station low-tension work, up to 800 or 1000 K. W. In the railway type, one machine is generally connected to an engine. In lighting, low-tension, direct-current work, two generators are generally coupled to one engine, one at each end.

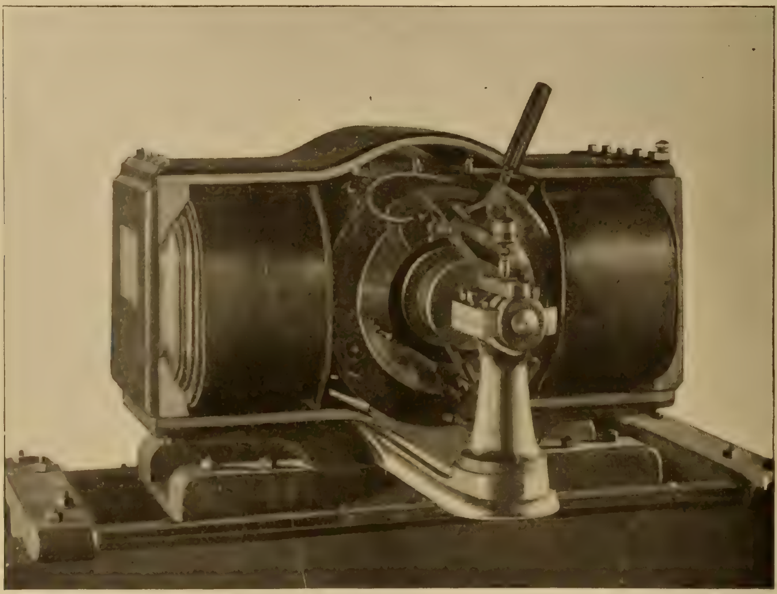
Alternating machines have been developed in as marked degree as the others, and to-day alternating generators are being built up to 5000 H. P. capacity, either for direct-belting or direct-connection, both in single-phase and multiphase type, and there is no question that alternating machinery has a large undeveloped territory ahead of it, especially for long-distance distribution, and the development of water powers.

Direct-current series arc-light ma-

chines have also been increased in their efficiency, and enlarged as to their capacity, so that now 150 or 200-light machines are common. The use of arc-lights on direct-current, incandescent circuits has been largely introduced and very successfully. Many companies have as many as six or eight thousand of these lamps connected to their circuits, and they are operating very successfully both for private and also for city street lighting. These lamps make a very profitable department of the companies' business.

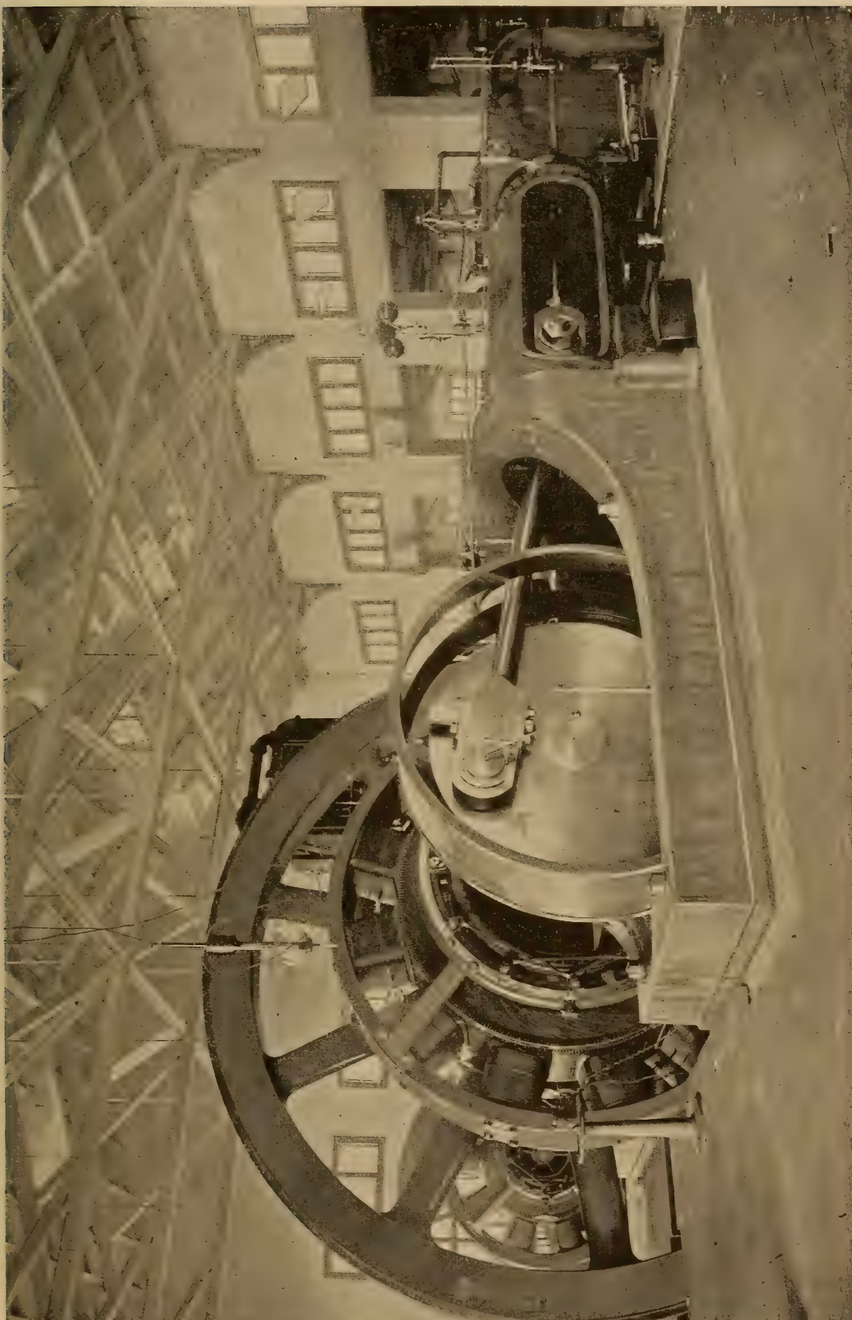
In the method of regulating and distributing the current and covering large territories from one central station, the development has been as great as that in apparatus. Formerly in the old type of direct-current incandescent station, the method of regulation was by expensive and cumbersome feeder resistance coils, to increase or decrease the resistance on each feeder, and keep uniform pressure at the ends of the line. This method has been almost universally superseded.

In one of the large stations that the writer built in 1888, he made one of the first departures from this practice by tying the feeder ends together by heavier mains, and equalising the pressure thereby, and also by introducing different bus pressures in the station, and running machines at different pressures, thereby doing away entirely with the feeder regulation. This method has been further extended and improved by the introduction of "booster" regulators as they are called, or small motor generators which increase or decrease the pressure on certain feeders and thereby effect the regulation and distribution for larger territories and ranges, and also enable a company with several stations to shut down their small sub-stations or outlying stations under light loads and operate from the main station at a higher pressure with a "booster."

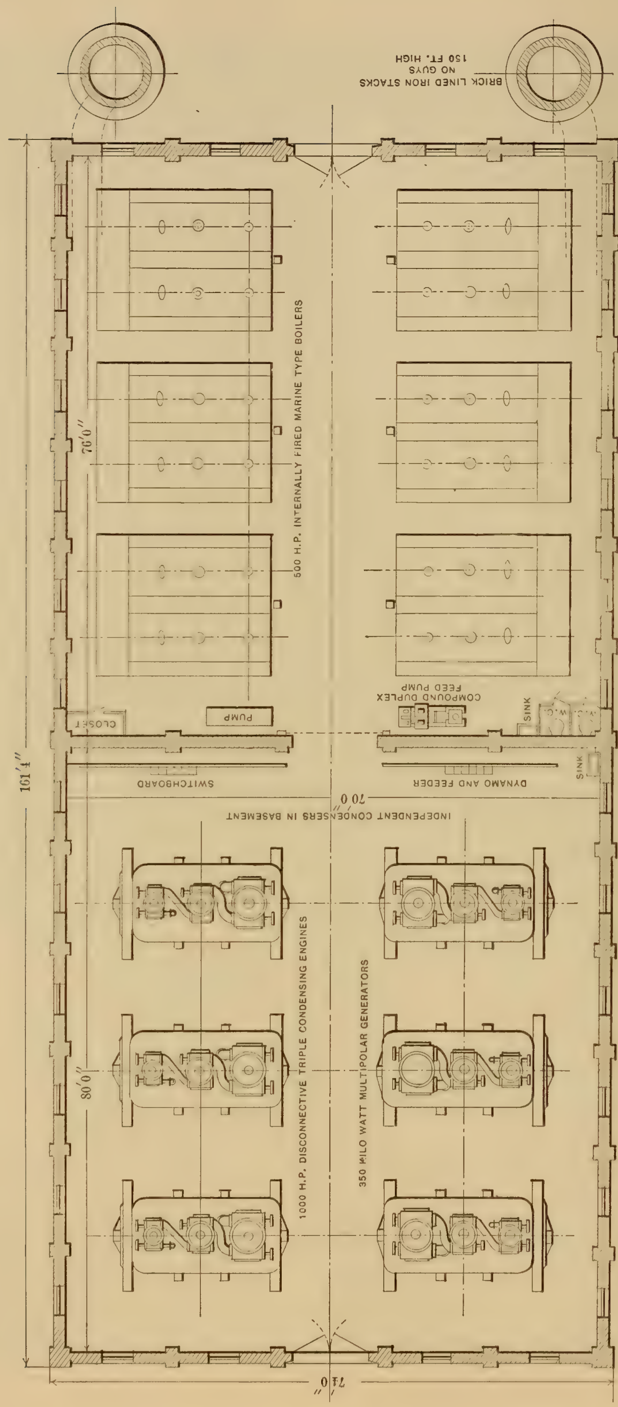


THE VANDEPOELE DYNAMO THAT FURNISHED POWER FOR ONE OF THE EARLIEST ELECTRIC STREET RAILROADS, AT SCRANTON, PA., U. S. A.

Storage batteries are beyond question to-day a commercial part of the central station lighting business. For several years in European practice they have been largely used commercially. It is only within the last two years, however,



1500 K. W. GENERATOR AND CROSS COMPOUND CORLISS ENGINE, BUILT BY THE E. P. ALLIS CO., MILWAUKEE, WIS., U. S. A.

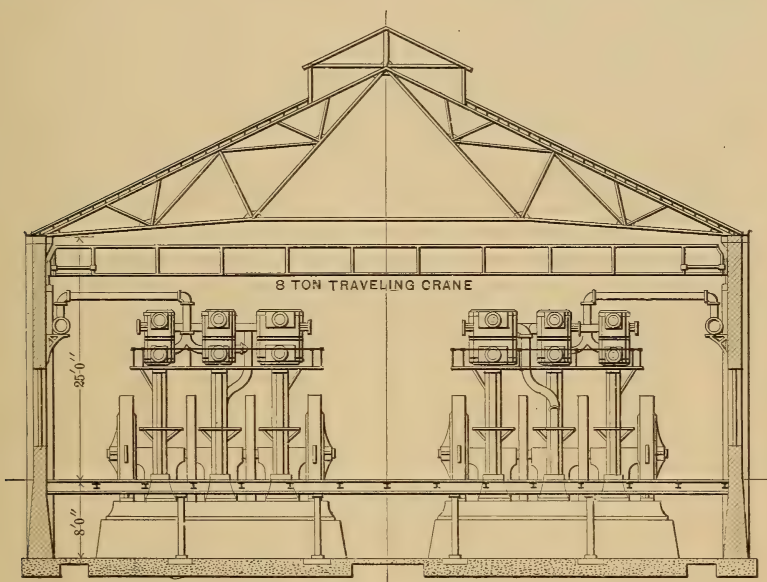


PLAN OF A CENTRAL POWER STATION, 6000 H. P., DIRECT COUPLED.

that they have been in successful commercial operation in the United States. The deterioration on them is now guaranteed by the manufacturers on a basis which makes them commercially adaptable, and there is no question as to their service under specific conditions, either to take light load hours or to take the peak off the heavy load hours, or for sub-station work in connection with main stations for certain hours. Under one or any of the conditions, when the case is fully considered, they have a useful and economical field.

Another important point in which there has been a radical change is the question of the location of the power station. Outside of arc light plants, it was the practice up to within four or five years ago to locate the station at the centre of electrical distribution, regardless of where the latter was. The result was that in a large system of lighting or power, the machinery was distributed over a number of smaller stations, instead of one large one, with consequently much higher operating expenses and poor economy in every respect. As a rule, such locations were not convenient for the economical generation of power.

The best practice has changed in this respect. One of the first examples that the writer had under his observation in which he managed to impress the directors with the advantage of this method was on a large railway plant of 7000 H. P. and about 150 miles of road, where it had been proposed to divide up the system into three or four stations. By concentrating it at one point, however, where water for condensing and coal from a side-track could be obtained, and by spending somewhat more money for feeder wires, the cost per kilowatt for manufacturing the current was reduced by a very large percentage under what had been obtained on any stations up to that time. This practice is further carried out in all large power and central station construction, and many of the companies are abandoning their old stations and building new and enlarged ones at points where power can be generated with the best economy, putting, also, an additional investment in feeder distribution capacity.

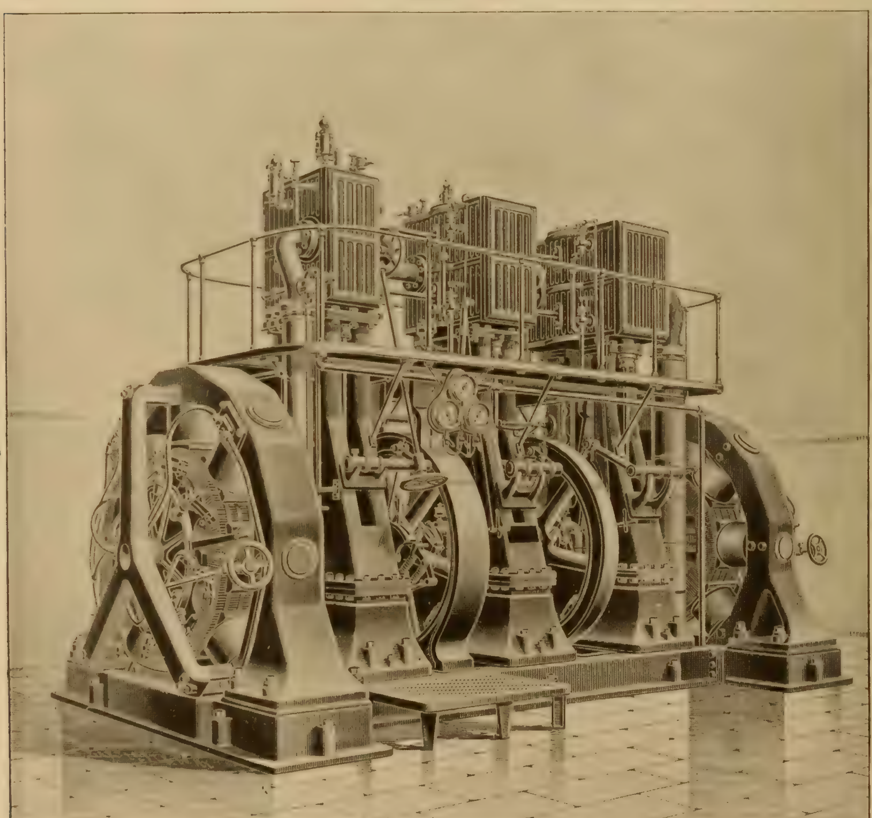


CROSS SECTION OF ENGINE AND DYNAMO ROOM.

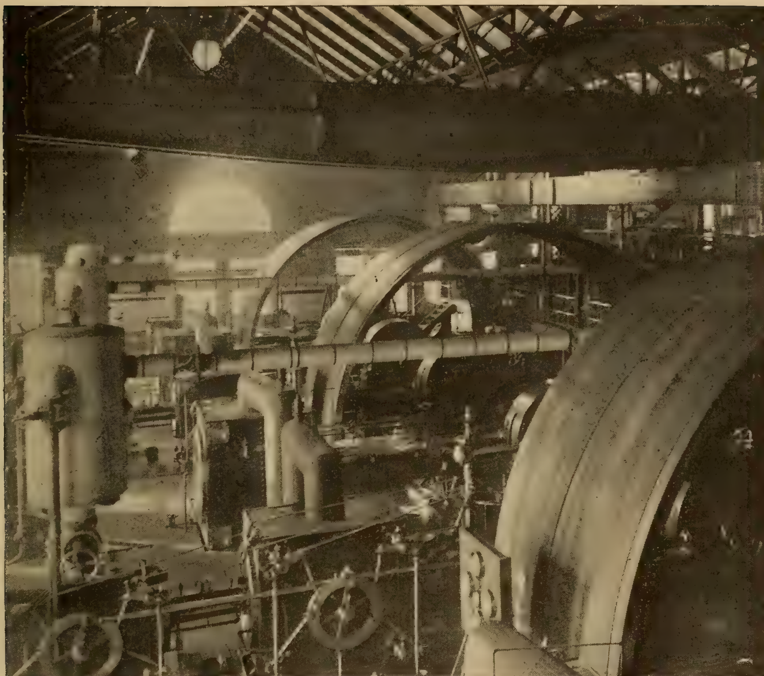
In some few special cases there may be a gain in locating a station away from these special advantages and nearer the electrical centre of distribution. For such cases we have a cooling tower condensing system, so that compound or triple-condensing engines can be operated with economy under those conditions ; where it is a railway power plant, the owners can haul the coal over their own tracks direct to the power house.

Feeder distribution and underground construction work, both for feeders and mains and distributing power for light purposes is being almost generally introduced in large cities, and is proving in every respect an ultimate gain and benefit to the power companies as well as to the public in general. For feeders from the power station to the distributing system there is no trouble whatever with several well-known systems. The main difficulty with an underground system for lighting companies is with the distributing mains where house-to-house service has to be introduced.

For low-tension current the Edison underground tubing system, with joints every 20 feet, is, beyond question, the best commercial practice. Insulated feeder cables for higher tension service, with man holes or junction boxes at every corner, and sometimes in between the blocks, and with the service mains running only from these boxes, has filled the requirements in other cases. Feeder cables for overhead trolley systems are now in use in several large cities, and are run in underground conduits. The system as



A TRIPLE EXPANSION LAKE ERIE ENGINE AND TWO DIRECT CONNECTED MULTIPOLAR GENERATORS.



IN THE POWER HOUSE OF THE WEST END STREET RAILWAY CO., AT BOSTON, MASS., U. S. A.

introduced by the writer at Buffalo, Philadelphia, and other places in the United States, were among the most successful in this respect.

The whole system of switchboard work has been much improved in its detail, so as to simplify the operation and enable an operator in the switchboard gallery to handle the largest possible amount of lines and generating apparatus with the least possible complication, and enable him also to have full control of the generating and distributing system under any and all conditions. The entire removal of wood or any kind of combustible material from the switchboard has been a great gain.

With this general review of the development and practice up to the present time, which has been intended to be only a general one and not specific in any respect, I will take up a part of the problem on which, to-day, in the technical press, there is an almost universal absence of any reliable data,—that is the present conditions for the economical generation of power from central stations, and the cost per kilowatt of power generated.

The kilowatt unit has been taken as the one best adapted for the conditions of practice in determining the cost, and is now almost universally used in figuring the capacity of generators and apparatus. For the information of those who are not familiar with this term, I will say that a kilowatt is one thousand watts, and the kilowatt-hour is the general basis in use. The kilowatt may be considered as $1\frac{1}{3}$ electrical H.P. and, transferred to the mechanical horse-power, is simply an allowance for the efficiency of the generating apparatus, which question we will take up further on.

The economy of the steam engine as the generating unit, driving the electrical generator, is one of the main factors in the cost in connection with the economy of power station work. The economy of these units, as we stated,

has been largely improved; the size of the units has been increased, and to-day stations are built with large units, adapted for variations of load for which the station is used. There is still in many cases and, in fact, almost generally, a considerable variation in the economy during the 24 hours, with the variations which hold in commercial practice, both in railway and lighting work.

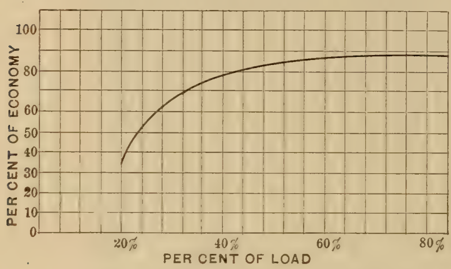


FIG. I. RATIO OF E. H. P. OUTPUT PER UNIT TO TOTAL I H. P. OF UNIT.

I do not know that we can better illustrate how this variation affects the pounds of coal per kilowatt than to instance an example which has come under my observation in a power station which is showing one of the best results that I know of. The variation in coal consumed per kilowatt during 24 hours is about as follows:—From 9 A.M. to 9 P.M., 4¼ to 5½ pounds of coal per K. W.—hour generated, charging everything up to the generation that should be charged. For the balance of the 24 hours the results run from 5½ to 9¾ pounds of coal. These figures are startling but they are facts.

We further illustrate this by showing the combined efficiency of the generator and engine unit as a whole in Fig. 1, showing, at 20 per cent. load, an output efficiency of about 35 per cent. of the ratio between electrical H.P. output and total indicated H.P. of the engine; at about 50 per cent. of the load the efficiency has increased to 80 per cent.; at 65 to 70 per cent. of the load it is up between 85 and 87 per cent., and the total efficiency is between 85 and 90 per cent. The figures show that units should not be operated at less than 50 per cent. of the capacity, and preferably at from 65 to 70 per cent.

The efficiency curve of the generator, Fig. 2, shows that the generator holds a higher average efficiency than the engine when we compare it with the combined efficiency of the engine and generator. This shows at 10 per cent. of load an efficiency of over 70 per cent.; at 25 per cent. load an efficiency of 82 per cent.; at 50 per cent. of load an efficiency of 91½ per cent.; at 75 per cent. of load an efficiency of 93 per cent.; and a full load efficiency of between 93 and 94 per cent. Test records

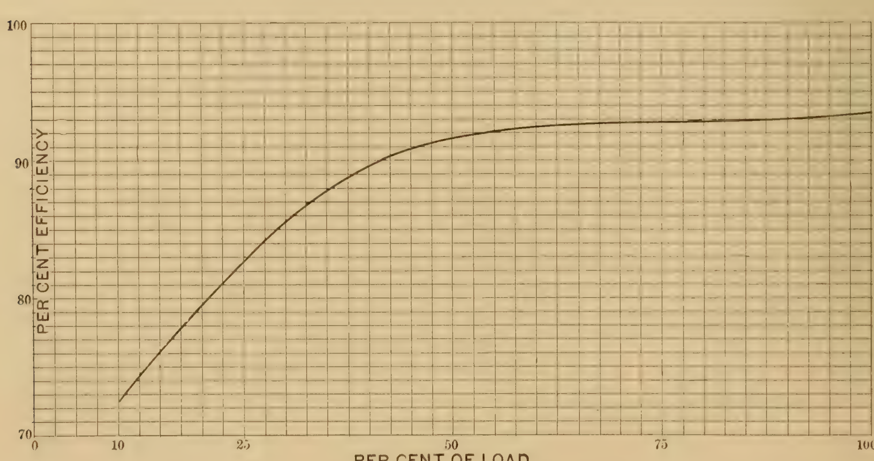
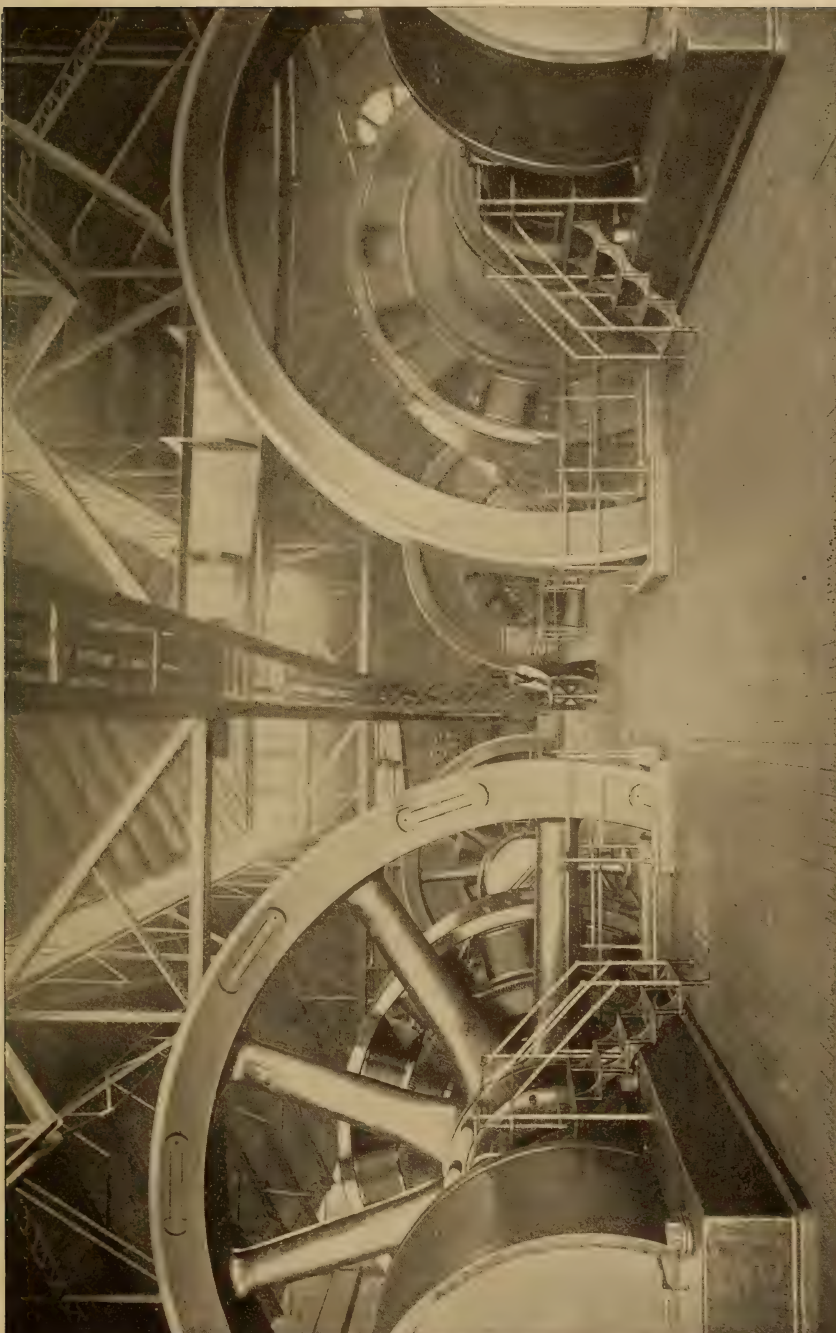


FIG. 2, CUVRE SHOWING EFFICIENCY OF A GENERATOR UNDER DIFFERENT LOADS.



POWER STATION OF THE BROOKLYN CITY RAILWAY CO., BROOKLYN, N. Y., U. S. A

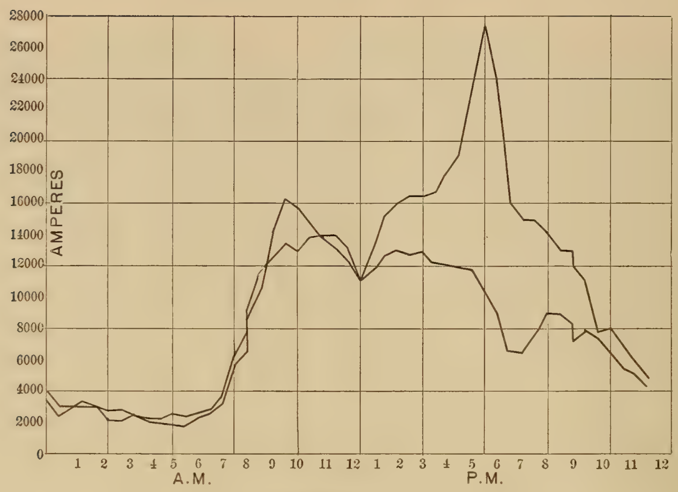


FIG. 3. LOAD DIAGRAMS IN A CENTRAL STATION.

show, in the best power stations, that with an efficiency of, say, three pounds of coal per K. W.-hour produced, for a unit operating at normal load, the station record, charging everything against the coal consumption for the 24 hours and taking the average loads under the best of conditions, would be about 4¼ pounds of coal per kilowatt for a week's record.

These 3 pounds of coal per K.W.-hour, transferred into pounds of water per H.P. generated, would be equivalent to about 15 pounds. It should not be understood that the engine will show this continually throughout the 24 hours, but under normal and constant load only, under the best conditions.

I have tried to illustrate by some load diagrams, an idea of the variations of load during different parts of the day for central station lighting and railway

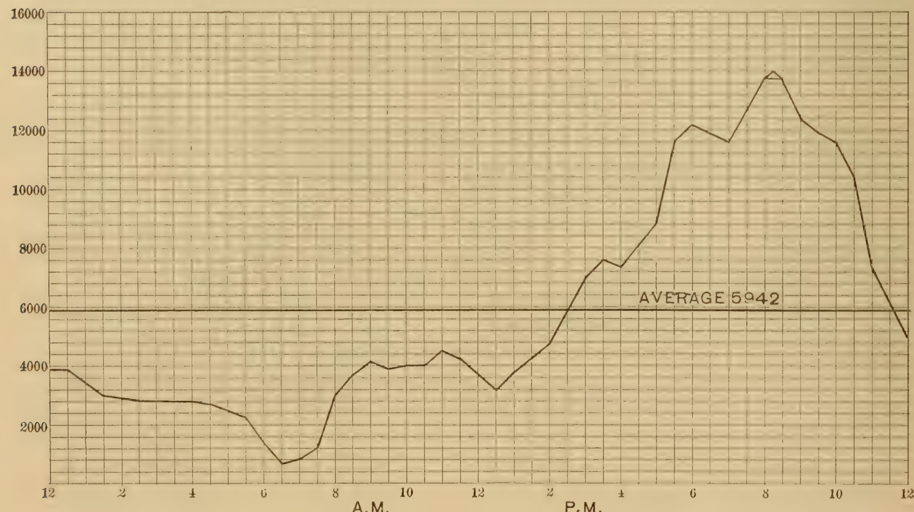


FIG. 4. LIGHTS CONNECTED IN ARC AND INCANDESCENT CIRCUITS, REDUCED TO EQUIVALENT IN 16 CANDLE-POWER = 90,000 LAMPS.

Maximum Load, approximately, 14,000 ampères = 28,000—16 c. p. lamps = 31 per cent. of connections.
Average " " 5942 " = 11,884— " " = 13 " " "

work. Fig. 3 shows two load days in a large central station, the one with the more average load being a dark, stormy day in the summer time, and the other being a December day, showing maximum load conditions between to station, both arc and incandescent, reduced to equivalent in 16 candle-power lamps, 90,000. The maximum load of 14,000 ampères is equivalent to, approximately, 28,000 sixteen candle-power lights, or about 31 per cent.

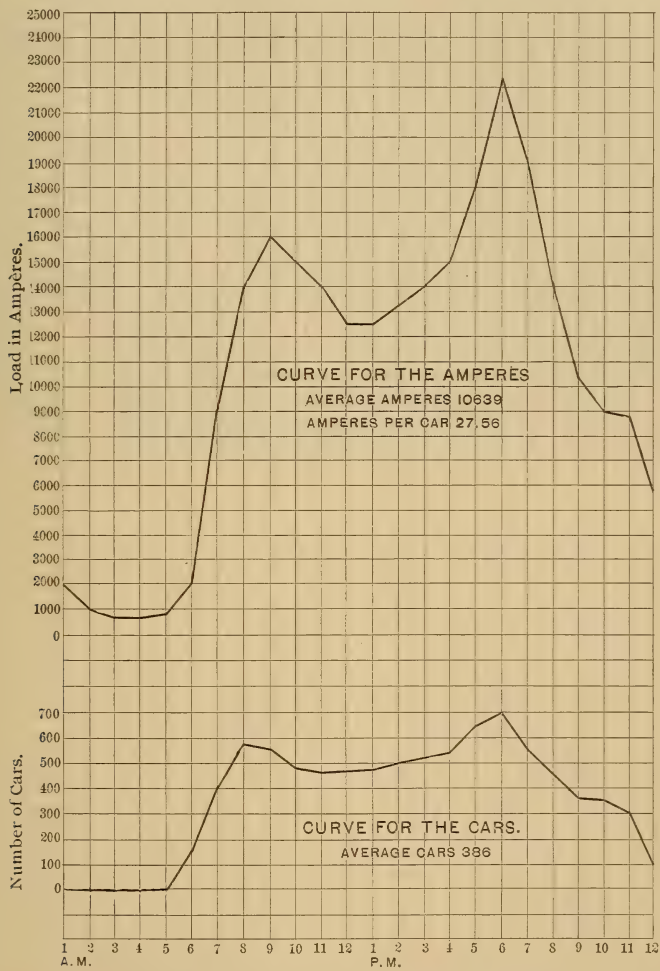
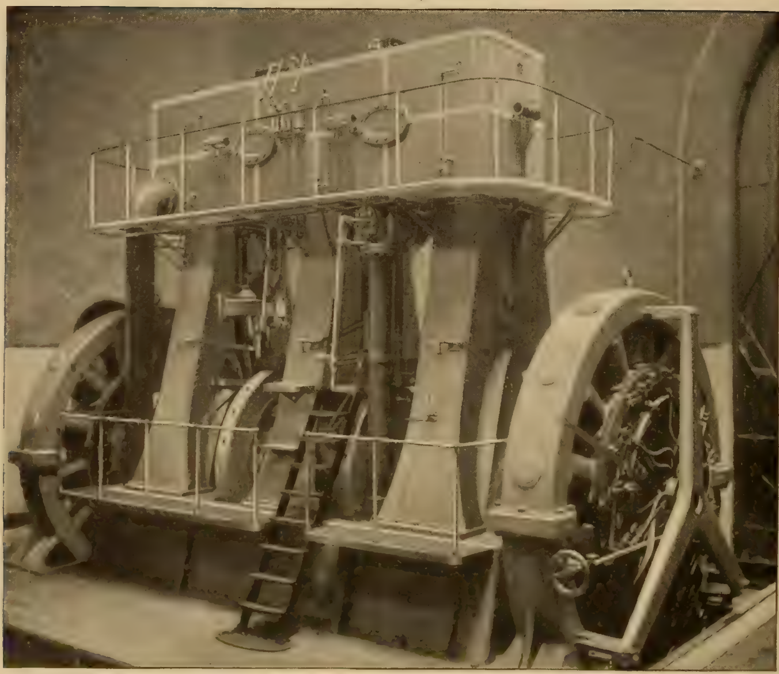


FIG. 5. LOAD DIAGRAMS IN A RAILWAY STATION.

nine and ten o'clock in the morning and between five and six o'clock in the afternoon.

Fig. 4 shows an example of a day in another station, and on it is given also the average load, which shows the following results :—Maximum load, 14,000 ampères ; average load for the day, 5942 ; total number of lights connected of those connected. The average load shows about 12,000 lights of 16 candle-power or an average of about 13 per cent. of the connections. This gives a good relative idea of the average and maximum loads in a large station, and their ratio to the number of lights connected to the station, showing that the generating capacity is not required to be



A WILLIAMS 600 H. P. ENGINE DRIVING TWO 200 K. W. GENERATORS. GUARANTEED PERFORMANCE, 13¾ LBS. OF WATER PER I. H. P. PER HOUR. BUILT BY MESSRS. WM. TOD & CO., YOUNGSTOWN, O., U. S. A.

more than from 30 to 35 per cent. of the total number of lamps connected, exclusive of reserve.

These diagrams also illustrate and show the need and requirements of averaging up the load during certain hours, by increasing the motor load during the light hours and offering special inducements to light and other customers for increased load during those hours. Electric companies have found that they can furnish motor power for a lower price per K. W. than lighting power, because it comes, as a rule, during a part of the day when the load is light.

All motor work, as well as lighting work, is now done by meter with much more satisfactory results. The average price at which power is furnished to large users for motor purposes is from six to eight cents (3 to 4d.) per K. W.-hour. On lighting work the average charge is 1 cent (½d.) per hour for a 16-candle-power lamp, with discounts to large customers, running from five to twenty or thirty per cent.

To illustrate a railway power curve is a difficult matter. The variations of a railway curve are often from maximum to minimum within a few moments. In a large station, with a large number of cars running, the load takes a more average condition and approximates more generally to the curves of prominent lighting stations, showing maximum points of load during the morning and evening rush hours when people are going to or returning from business. Fig. 5 illustrates the general average fluctuations of load, without indicating the momentary fluctuations. It gives also a load diagram showing the average changes for the number of cars operated during the entire day.

In conclusion I wish to show by two tables what the cost per kilowatt is both for railway and central station work, in the best practice to-day and the general results indicated. The cost of

the manufacture of current per kilowatt-hour in a large modern station for lighting, from actual log records, the plant being triple-condensing, with direct-connected generators, with steam pressure of 175 pounds, is as follows :—

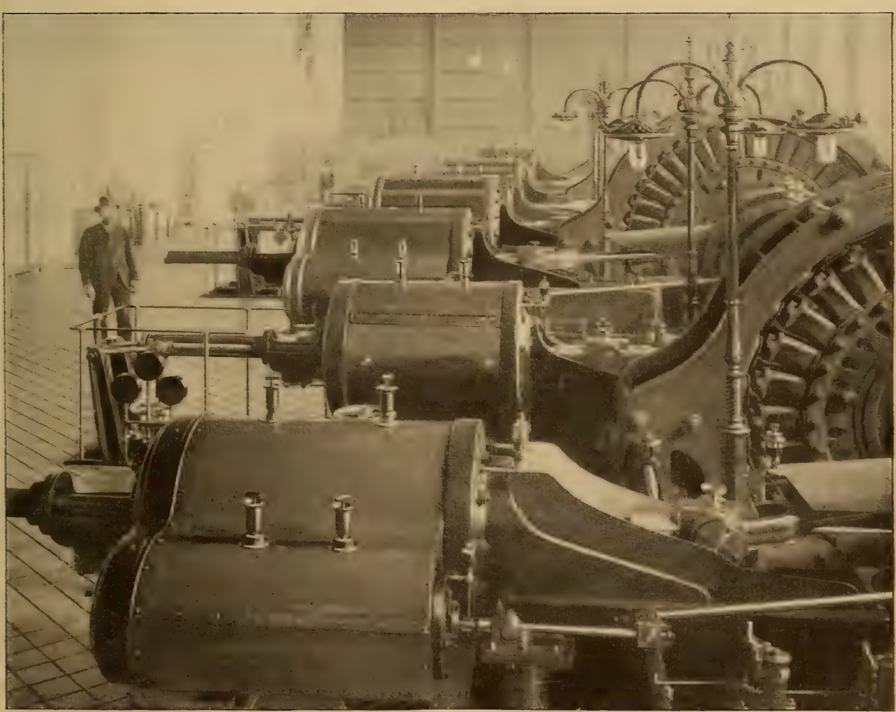
Water, cost	.060	
Coal, pounds		4.25
" cost	.515	
Removal of ashes	.026	
Lubrication, waste packing	.022	
Labor, engines, boilers, dynamos, and miscellaneous	.62	
	1.243	cents
Cost of distributing, including care of overhead and underground lines, house wiring, lamp renewals and meters	.767	
	2.010	cents
General executive expenses, including office expenses, and taxes	1.55	
Total	3.560	cents or about 1.78d.

These results show practically 1¼c. (.625d.) per K.W, for manufacture of the current, ¾c. (.375d.) for distributing the current, and 1½c. (.75d.) per K. W. for general and executive expenses. This makes the total expenses of the station in question approximately 3½c. (1.75d.) per K.W. hour. Going further into this, we find that the coal is approximately 40 per cent. of the cost of manufacture, labour is 50 per cent. of the cost of manufacture, and the total manufacturing cost is 35 per cent. of the whole, with the total distributing cost 21 per cent. of the whole, and the general and executive expenses 44 per cent. of the whole. With increase of business, the general and executive expenses show a smaller percentage of the total ratio. Some stations show a better average on parts than this one, but I have found none that show a better average as a whole.

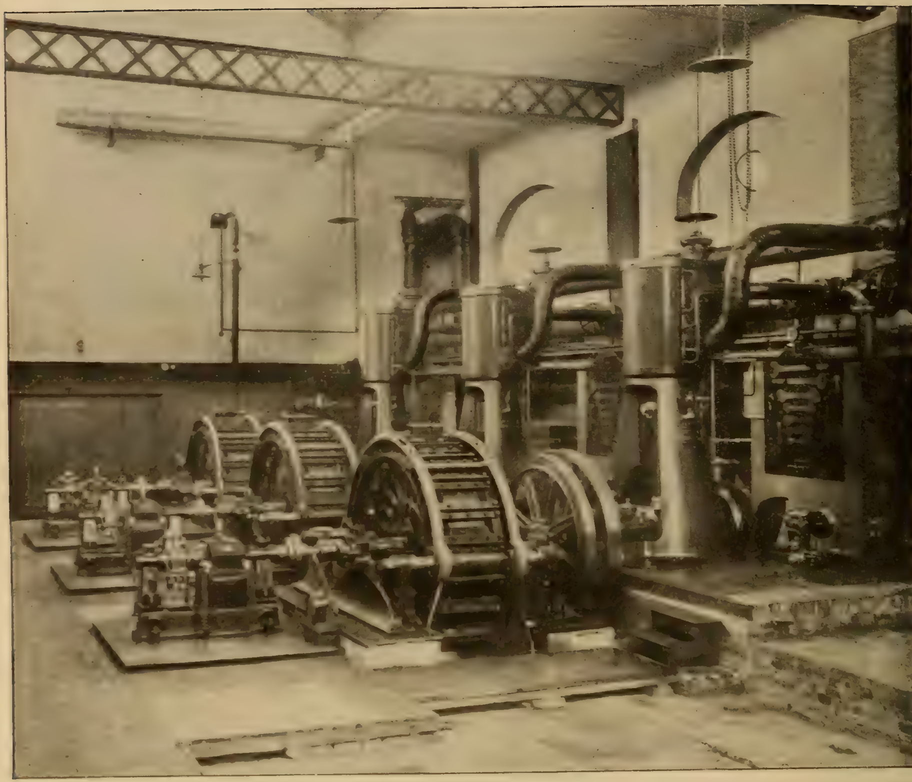
On railway work, with compound engines and direct-connected units, operating at about 130 pounds steam pressure, we have the following results :—

Operating Expenses.

Coal at $3.50 (14sh.) per ton	$2,454.50	(£490 18sh.)
Labour	1,325.00	(£265)
Oil, waste and repair	265.50	(£53 2sh.)
Total	$4,045 00	(£809)



A CENTRAL STATION AT MILAN, ITALY.



ANOTHER ITALIAN CENTRAL STATION INTERIOR.

Taking the total number of cars operated and the car mileage for the month, this being the total expenses for a month, we find that the average cost of power per car-mile is one cent (½d.), the cars being almost entirely 18-foot single-truck cars. The grade conditions and general service are the average. Transferring this cost of car mileage into cost per K.W. manufactured, determining this cost both from station records and car test of power consumed, we have approximately .9c. (.45d.) per K.W.-hour as the cost of manufacture, in which the coal is approximately 63 per cent. of the manufacturing cost, labour 33 per cent., and oil, waste and repairs, 4 per cent.

I believe we are fast approaching the time when we will show, if we are not already doing it, in some stations, a result in the cost of manufacture per K.W.-hour equal to one cent (½d.) for lighting stations and ¾c. (.375d.) for railway stations. The examples indicated here are authentic cases, taken from actual records obtained.

It may be of further interest to indicate in a general way what such a central power station would cost per K.W., say one of 5000 K.W. capacity:—Steam plant, $85 (£17) per K.W., including engines, boilers, pumps, heaters, condensers, piping, etc.; electric plant, including generators, switchboard, cables, etc., direct connected units, $30 (£6) per K.W.; power station, building under average building conditions of good foundations and no rock excavation, including foundations, building, stack, etc., $15 (£3) per K.W.; sundries $10 (£2) per K.W. This makes a total, $140 (£28) per K.W. This is exclusive of real estate.

PROTECTION OF ELECTRICAL APPARATUS AGAINST LIGHTNING.

By Alexander Jay Wurts.

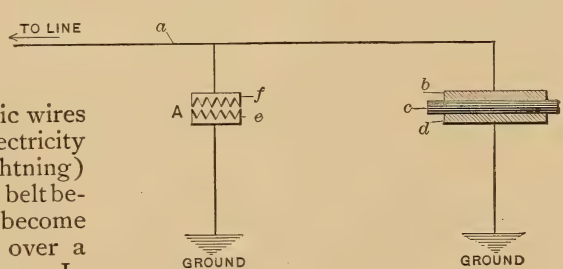
A POLE LINE IN A MOUNTAIN SNOW DRIFT.

A LIGHTNING arrester in its typical form is represented at *A* in the diagram on this page. It consists essentially of two pieces of metal insulated from each other and separated by a small air space called the "spark gap." If one of these metal pieces be connected to an overhead wire, and the other to earth, the lightning arrester is said to be installed. During thunder storms sparks will leap over the gap and a kind of electricity,—static electricity,—foreign to the dynamo or useful current, will thereby escape from the line to the earth.

During thunder storms, electric wires become charged with static electricity (they are seldom struck by lightning) very much as a dynamo or engine belt becomes charged, or as our bodies become charged when walking briskly over a thick carpet on a dry winter day. In either case the electric charge is called "static electricity," meaning electricity at rest, and sparks, called "static discharges" or "disruptive discharges," can be drawn from the belt or the body.

Benjamin Franklin with a key drew such sparks from his kite string. If Franklin had held a sheet of paper between the key and string, the sparks would have perforated the paper. If a second person had then placed a second key in closer proximity to the string than Franklin's key, nearly all the sparks would have passed or have been diverted to the second key. The paper would not have become perforated; the second key would have protected the paper and could properly have been called a protector or diverter. To-day a similar device is called a "lightning arrester," which name is, obviously, a misnomer.

If we strip an electric installation of all its features, save those which concern protection against lightning, we shall find Franklin's kite string, the two keys and the sheet of paper. Referring, again, to the diagram, *a* is the overhead wire or kite string; *b* is the copper wire of an armature,—the end of the kite string; *c* is the insulating material in the armature, which may represent the sheet of paper; *d* is the iron frame of the motor or dynamo,—the first key;



A TYPICAL LIGHTNING ARRESTER.

and *e* is the lower half of a lightning arrester,—the second or protecting key,—in close proximity to the over-head wire (the string), of which *f* is electrically a portion. This lightning

arrester is said to protect the motor ; it diverts the spark to earth rather than allow it to perforate the insulation of the motor.

A lightning arrester of the above simple form, while it allows the spark to pass, will also allow the dynamo current to follow and thereby establish a dangerous electric arc. Many devices have been invented which have for their object the extinguishing of this arc. Any such device is, however, a remedy rather than a preventive. A more desirable form of lightning arrester is obviously one which would allow the sparks to pass without the accompaniment of the dynamo current. Such lightning arresters, called "non-arcing" arresters, have been designed.

A lightning arrester connected in the neighbourhood of a motor or generator does not necessarily protect that apparatus. If the insulation of the apparatus be weak or defective, the apparatus is quite as likely to protect the lightning arrester as the lightning arrester is to protect the apparatus. If the lightning arrester is to protect, the insulation must be sound and of a definite strength.

And, yet, even with the best of insulation, a lightning arrester does not always protect. The reason for this is not obvious. That which we see and call a lightning flash is not a simple passage from a cloud to the earth ; it is a vibration. The lightning oscillates back and forth. The oscillatory character of lightning and of disruptive discharges, in general, gives rise to complicated phenomena. Electric oscillations, or waves, interfere with one another much as water waves do. If a trough of water be raised at one end and then quickly lowered, the water in the trough will quietly surge back and forth. If the end of the trough be raised a second time a new system of surging may be started in such a manner that the two will interfere with each other and cause splashing at certain points where crests of the two systems combine to form higher crests. Calm or smooth surfaces will be noticed at points where a crest of one system has been neutralized by a trough of the other system.

In electric wires we have somewhat analogous conditions during thunder storms ; we have what a sailor would call a choppy sea. The calm places and splashing places are very close together, so that (and now we come to the point we are looking for) a lightning arrester, for aught we know, may be connected at a calm place or at a splashing place. If at the former, no discharge will take place at the arrester and the apparatus is liable to become damaged. If at the latter, however, a discharge will take place and the apparatus will be protected. But these splashing places are constantly shifting their positions. How, then, is a lightning arrester to be properly located? Answer,—By connecting such a number of lightning arresters along the line that several of them are likely to be found at splashing places. Possibly arresters which are at splashing places on one occasion, may or may not be found at such places on some other occasion. The number of arresters should, therefore, be such that for all conditions some of them at least will be found at splashing places. The above phenomenon of shifting splashing places gives the disruptive discharge a selective character.

In some instances, when the electromotive force of the circuit is high, it becomes necessary to increase the spark gap of the lightning arrester so that the normal pressure of the circuit may not strike an arc ; but an increase in the spark gap obviously increases the resistance in the lightning arrester to the passage of the discharge. To offset this, a resistance is placed between the arrester or arresters and the apparatus to be protected. An oscillatory discharge possesses the property of self-induction ; it therefore passes with difficulty through coils of wire. Moreover, the frequency of oscillation being incomparably greater than the frequency of commercial alternating currents, a coil can readily be constructed which will offer a relatively high resistance to the passage of disruptive discharges, and at the same time allow free passage to all ordinary electric currents. A coil of wire called a "choke coil" is

therefore the resistance which is ordinarily placed between a lightning arrester and the apparatus to be protected.

The problem of protecting electric apparatus against lightning has not been altogether one of invention; it has been quite as much one of careful and patient observation. Four years ago it was customary to place a single lightning arrester at the point where protection was desired. To-day the same point is protected by distributing line arresters at frequent intervals over the system. This change has resulted partly through the invention of more simple and effective lightning arresters,—instruments which can be trusted at a distance from station attendants and which are free from the necessity of occasional inspection; but perhaps more through a more complete understanding of the problem,—of the conditions which have to be met.

The most important characteristic of static discharges from electric circuits is that of selection. Discharges do not, as has been commonly supposed, follow the "shortest and easiest path to earth." Were this the case, one arrester carefully installed would be all-sufficient. The discharge being selective, it is very certain that one arrester is not sufficient, and further, if line arresters be connected at frequent intervals, the path which will be selected will more and more likely be one of the arresters rather than the apparatus, in proportion as the number of arresters is increased. This statement is sustained in practice by the rapidly growing use of line arresters. Station arresters are perhaps advisable as an extra precaution, but in general, discharges entering the station offer a fair indication that more lightning arresters are needed on the line.

The question naturally arises: "How many lightning arresters should be connected to a given length of circuit?" The writer recommends four to the mile of wire, but this is by no means to be taken as an invariable rule; much depends upon the local conditions, the character of the soil with reference to ground connections and liability of lightning to strike, the grade of insulation to be protected, the voltage of the circuit, which latter governs the safe spark gap length which may be employed, and the surroundings with reference to telegraph and telephone wires.

In general, thickly settled districts tend to decrease the number of lightning arresters which may be required.

During the past two years the writer has conducted a series of experiments, with the idea of more specifically determining the number of lightning arresters per mile of wire which would offer reasonable security to well-insulated apparatus. But, so far, although the results have been perfectly satisfactory as regards protection, the specific object of the experiments has not been attained. On a five-mile circuit lightning arresters were distributed one hundred feet apart.

The results obtained during the past year indicate that during eleven storms the number of arresters which received discharges in each storm varied from 9 to 55. This would seem to indicate that 55 arresters instead of nearly 300 would have protected the plant, but it has not been demonstrated that 40 or even 30 might not have done equally well, or that 60 or more arresters might not have been necessary for a plant otherwise situated. The information which has been derived from this particular case, though interesting and useful as far as it goes, fails in its general application.

I have therefore communicated with some of the more prominent electric light and power plants in the United States, asking for information regarding their respective experiences in connection with line arresters; how these are distributed, how grounded, whether line arresters have materially decreased their losses from lightning, and whether their plants now operate satisfactorily through thunder storms. Data collected from so broad a field is naturally varied in its character and therefore capable of general application.

Prompt and willing answers have been received in almost every case and I take the present opportunity to express my

ELECTRIC POWER OVER THE MOUNTAINS.

appreciation and thanks to all who have so courteously assisted me in this work. In the letters which follow I have taken the liberty of condensing and occasionally omitting portions which would not materially add to the fund of information. Names of lightning arresters are also omitted.

Mr. C. E. Doolittle, Manager of the Roaring Fork Electric Light and Power Company, at Aspen, Colo., wrote on October 1, 1894 :—" We have suffered no damage to our 500-volt generators or motors from lightning this summer. We connected arresters to ground plates 30″ square, buried under the irrigating ditches and we have an arrester for every 400 feet of pole line, except in a few places where it was impossible to get a good ground." Mr. Doolittle up to that time had been greatly troubled with burn-outs from lightning and in the spring of 1894 wrote for specifications regarding the proper protection of his plant. These were furnished and carefully carried out with the above results.

Mr. E. Woodruff, Vice-President and General Manager, Atlanta Consolidated Street Railway Company, Atlanta, Ga., June 26, 1895 :—" Since adopting your plan of protecting our station from lightning we have had no trouble whatever and although we have had a number of severe thunder storms, our circuit breakers have not been out this season on account of lightning. After having suffered so much inconvenience and expense last season I feel grateful for the valuable service you have rendered us." Mr. Woodruff had, as indicated, experienced a great deal of trouble from lightning and requested me to send him specifications for a proper installation of lightning arresters. Line arresters at frequent intervals were advised and to their use the writer attributes the above favourable results. Mr. Woodruff also uses tank arresters in his station.

Mr. James L. Devenny, Manager, McKeesport, Duquesne and Wilmerding Railway Company, August 2, 1894 :—" We are much pleased with the manner in which the lightning arresters have protected our line this summer. During the severe electrical storms no lightning has been evident in the power house. Our cars have run as usual without any disturbance whatever. Last summer we were compelled to shut down during very light storms." This line was equipped with arresters every 100 feet and was the subject of some experiments by the writer

mentioned elsewhere in this paper. Mr. David Barry, Superintendent of the Amherst Gas Company, Amherst, Mass., August 13, 1895 :—"We have eight line and two station arresters. They are not placed at regular intervals, but at exposed places along the line. We have one long circuit, covering quite a large area, and one section runs along a very exposed ridge on which the lightning strikes during nearly every thunder storm. There are five arresters distributed along this section, which is about half a mile in length, and they have not yet failed to protect it.

"A few weeks ago a house was struck, demolishing the chimney and causing considerable damage to the upper part of the house. The discharge then passed out over the secondary wiring raising havoc with a transformer and going to ground through a lightning arrester 100 feet away. There is no doubt but that considerable damage has been averted by the use of these arresters, as we have no trouble in operating through thunder storms of unusual severity. We attribute this chiefly to the arresters ; partly, however, to the fact that our circuits run in many places through trees. We grounded the arresters by soldering the ground wire to the end of a gas pipe and driving the pipe into the ground six or eight feet."

Mr. W. L. Githens, Manager, Hyde Park Electric Light and Power Company, Chicago, August 3, 1895 :—"I have about 50 miles of incandescent feeders, mains and branches. Early in June I placed twenty-four double-pole arresters on my lines, beginning at the farthest points. Previous to this time we had depended fully upon two station arresters, of which sad experience teaches me is not protection. We have experienced some unusually heavy electrical storms since the installation of the new arresters, but at no time have we been compelled to close down a second, which I cannot say was the case previously. However, I think it advisable to double the

MAKING LIGHTNING ARRESTERS.

number of arresters I have up and shall do so at an early date.

"As my arresters are now placed, the distance between them varies from 5000 to 15,000 feet. We ground our arresters by driving a ¾" pipe into the ground about eight feet, to which we connect a No. 6 W. P. wire leading to ground lines of the arresters. All connections are thoroughly soldered. Even with the number of arresters now up, station damage has been eliminated. I think, though, that a perfectly protected line should have arresters about every 3000 feet apart."

Mr. C. R. van Trump, Engineer and Manager, Wilmington City Electric Company, Wilmington, Del., August 8, 1895 :—"We employ about 30 line arresters at points where we appear to be subject to lightning, at both ends of all cables and where lines pass over hills or in open country, also at large transformers and at ends of the lines. We make grounds by means of a heavy copper plug, into which we bore a hole and solder a piece of No. 6 rubber covered wire, insert the wire into a ¾" wrought iron pipe 6 feet long and fill the pipe with compound, driving it into the ground within 6 inches of the top and run the wire up the pole without joints to the arresters. Thunder storms do not affect us, whereas, before using the arresters, they always went hand-in-hand with costly trouble."

Mr. O. S. Lyford, Chief Engineer, Siemens & Halske Electric Company, Chicago, August 14, 1895 :—"Power circuits are protected in every case at the dynamo ends by means of main lightning arresters, either the tank type or the spark gap type. In addition to this it is customary for us to equip the lines with arresters, using generally one per mile of conductor. In railway plants there is always more or less inconvenience caused by the opening of circuit breakers when there is a lightning discharge. It has been our experience that the use of line arresters reduces this difficulty to a large extent. We thoroughly agree with your recommendation that the arresters be carefully grounded, and it is our custom to use a ground plate of copper, with a foot or more of broken coke or charcoal above and below the plate, the whole being placed low enough in the ground to insure sufficient moisture."

Mr. J. B. Henny, General Manager, Hartford and West Hartford H. R. R. Company, Hartford, Conn., August 5, 1895 :—"We have 75 line arresters on our railroad system. We have ten miles equipped in this way. Where we go through heavy woodland and over the mountains, the arresters are connected to every side tap, and that would bring them about 625 feet apart. In places not so liable to be troubled by lightning, we have about seven to the mile. They are connected on the ground side to the bond wire,—two No. 0000 on each joint, without any return wire in the middle of the track. We have had this summer some of the most severe thunder storms that have been known in this locality for the past ten years, and we were able to operate continuously throughout these storms without any damage to the machinery in our station or the cars on the line, the only exception being one lighting circuit which was burned. We also have in our station a lightning arrester on each feed wire."

Mr. W. R. Gardiner, Asst. Manager, Pittsfield Electric Company, Pittsfield, Mass., August 3, 1895 :—"We put up during the winter thirty-six line arresters for our alternating lines, and also ran an iron wire over all the circuits, well grounded about every 1000 feet. The lightning arresters were not attached to this iron wire, but were grounded separately. Our grounds are made by digging a hole 8 feet deep and driving a 1½" galvanized iron pipe 12 feet, and filling the hole 6 feet from the bottom with pulverised coke. So far, this year, we have had but three thunder storms, and they were very light. We, however, lost two transformers."

Mr. B. B. Nostrand, Jr., President, Peekskill Electric Light and Power Company, Peekskill, N. Y., August 5, 1895:—"Two years ago we equipped the station with arresters which

worked satisfactorily, and since that time we have had no trouble in the station. However, in one storm last year we lost twenty converters more or less damaged by lightning. This year we have placed line arresters on all the lines at intervals of about ¼ of a mile, connecting the arresters with the ground plates by a 3-16″ iron strand. The ground plates were made of No. 20 galvanized sheet iron, the shape of a cylinder, 11″ in diameter and 18″ high, and were buried at the foot of the poles, deep enough to insure damp earth, a half pound of fine coke being tamped about the plate. The joint between strand and plate was washed and painted over with P & B paint to prevent it from local action. This latter may not have been necessary, but was done as an extra precaution. We have not, so far, this year, had as severe storms as last, although we have had some quite heavy ones, but the arresters have protected us from any damage from lightning. We have suffered damage by lightning in the past during thunder storms of no greater severity than we have had this summer, and we feel very well satisfied with our investment in line arresters."

Mr. E. D. Alexander, Vice-President, Englewood Electric Light Company, Chicago, Ill., August 6, 1895:—"We are using on our lines 65 line arresters, and by their use have reduced our transformer loss from lightning to a very small annual amount. Since we have used them at our station we have as yet failed to have a fuse blown by lightning passing them. We consider them indispensable during thunder storms."

Mr. C. A. B. Hauck, Lehigh Traction Company, Hazelton, Pa., August 3, 1895:—"As far as we are able to judge, the damage to our line by lightning has been greatly reduced by the use of arresters. We have them placed one to every 1300 feet of No. 0000 feed wire on our South Side branch, and one to every 1800 feet on the North Side; also on West Side and Milnesville, one to every 1800 feet of No. 0000 feed wire. We placed these arresters where we could secure the best ground, at the same time choosing the best location as far as the topography of the country was concerned. We have about 110 arresters on our line all told. One terminal wire of the arrester is connected to the bridging of the feeders, the other to a square foot of boiler iron, placed five feet in the ground, into which is riveted a No. 00 tinned copper wire which is long enough to reach the web of the rail, and into which it is very securely riveted. We have operated our line through thunder storms to our satisfaction, except, of course, when the storm became so violent that we deemed it advisable to shut down for a few moments.

I may add that Hazelton seems to be visited with more penetrating and violent lightning than any other place with which I am acquainted east of the Rocky Mountains. This may possibly be due to the coal regions and the fact that in that locality the coal beds are near the surface."

Mr. G. E. Wendle, Electrician, Lycoming Electric Company, Williamsport, Pa., August 15, 1895:—"Our incandescent A. C. circuits are protected with line arresters, and we run through everything 24 hours a day with a small percentage of converter burnouts. On our arc circuit we have no line arresters. In the station, one on each side. The principal trouble we have with lightning has been on our railway lines. This spring we placed arresters about every 1000 feet on the lines and choke coils in series with the line feeders. In ordinary lightning storms we have run through without damage. When the storm is particularly violent, circuit breakers are thrown out very frequently. We usually open the circuit breakers and wait until it passes over. We feel that we could run safely perhaps, but we are running so close to full capacity that it makes it unadvisable to take any chances. We have 52 arresters on our railway lines and 20 on our alternating current circuits."

Mr. Wendle enclosed sketches showing the construction and method of

connecting his choke coils, which is very similar to that shown in Fig. 3; also sketches showing the method of making his ground connections, which is same as that shown in Fig. 1, with the additional feature of connecting the upper end of the iron ground pipe to the bond wires.

Mr. Alexander Dow, Engineer, Public Lighting Commission, Detroit, Mich., August 7, 1895:—"We have had a number of odd experiences on our towers with atmospheric electricity. The vertical wiring of the towers has been found strongly charged, and slight shocks to the men working on the towers have been frequent. The vertical wires are carried inside the triangle formed by the horizontal framing and parallel to the verticals. I believe that the towers themselves discharge harmlessly much atmospheric electricity that would otherwise create disturbance on our lines.

"Answering your questions categorically, I consider line arresters necessary on all exposed circuits. So far we have erected only six pairs. These are not distributed systematically with a view of protecting the system as a whole, but are located where long loops join the main line. We expect to install about 20 pairs of these arresters all in similar locations. On the same poles with the lightning arresters we place loop switches to cut off the loops in case of trouble. The ground connections are of two No. 6 copper wires, twisted together and ending in a coil buried at the foot of the pole. We put above and below the coil, coke or hard coal and drive through the coke and convolutions of the copper wire five or six pieces of gas pipe from three to five feet long. These, of course, reach permanently damp earth, from eight to ten feet below the surface.

"We operate through thunder storms satisfactorily. There is an occasional spit on the dynamo lightning arresters, but only in one instance has any noticeable discharge come into the power house. The ground connection for the dynamo arresters is a No. 6 stranded cable, connecting to a galvanised iron pipe under the floor. The pipe is 1″ in diameter and is connected in two places into our general system of steam piping. Last year we had a pole struck by lightning before the wires were strung. This was in a district of the city where there are few towers and these far between. But for this occurrence, I would believe Detroit electric lighting installations specially exempt from lightning troubles and would attribute this to the 238 towers of 100 to 150 feet which are standing in the city. Still, I propose to have line lightning arresters where the loops which run out on the prairie join the main line."

Mr. James Fagen, E. E., Wilkes-Barre and Wyoming Valley Traction Company, Wilkes-Barre, Pa., August 11, 1895:—"We have 150 line arresters, distributed over 50 miles of line; on long suburban lines they are placed about 500 feet apart. All are grounded to a one-inch galvanized pipe, driven into the ground 8 feet; also connected to rail where practicable. Ground is sandy or coarse gravel, inlaid with rock, and in most places saturated with water at that depth. We always operate through thunder storms and have lost very few motors this season as compared with other seasons, although operating 10 per cent. more cars."

Mr. J. M. Almstead, Superintendent Citizens Light and Power Company, Rochester, N. Y., August 5, 1895:—"Line arresters have proved very satisfactory in protecting our lines against lightning. We have just passed through a severe electric storm with light and power circuits running; have never shut down through electric storms since placing the arresters on our lines and have experienced no trouble, except the burning out of one converter which was quite a distance from any arrester. We have 80 arresters in use and contemplate placing more of them; we consider them a good investment and a cheap insurance against lightning.

"In regard to placing them on the lines,—on the power circuits we con-

nect one arrester to both sides of the circuit near the point of entering the building where motors are located. We also connect one arrester to underground cables where the junction is made to overhead lines. We consider it very essential to make good ground connections by digging down to damp earth and burying copper plate connected to ground wire. Of late, we have used two plates, placing the first in damp earth, then filling in with a layer of charcoal, and over this placing the second plate, connected to ground wire, and finally filling up with earth."

Mr. A. Green, Supt., Rochester Railway Company, Rochester, N. Y., September 13, 1895 :—"In our power station at Rochester the lightning arresters were formerly placed inside of the station, but these have since been removed to the outside of the wall, and in doing so I grounded the arresters with a 500,000 circular mill cable, clamped to a 24 inch copper plate, one inch thick, which was buried in the mill race. The cable is not soldered to the plate, so we have no chemical action produced by dissimilar metals, and I am pleased to inform you that during our most severe electrical storms we have not had a single discharge in the power house. Our station at Charlotte is similarly equipped and while it used to be a regular thing for them to have an armature burned out, we have not had any trouble at all this season.

"In regard to line arresters, I would say that we have not many in use at present, but are increasing our number as fast as possible. In our experience connecting lightning arresters with the rail as a ground, we have found it a dismal failure. Where it is practicable, we dig deep enough to find water, then bury a 12-inch copper plate, to which we ground the line arresters with No. 0000 wire. If we cannot reach water at a reasonable depth, we dig four or five feet, put in a copper plate, then, on top of that, put five or six inches of lump charcoal, and then another copper plate, to which is clamped a No. 0000 wire, connecting with the ground terminal of the line arrester. This has given splendid satisfaction, more especially on our suburban lines, where we had no end of trouble in times past. We have now about 140 lightning arresters in use.

"I have given car arresters a great deal of thought and attention, and while I may be wrong, I have come to the conclusion that the place for the arrester is at or near the trolley base, and that the arrester should be provided with a ground wire having a cross-section twice that of the lead to the motors. We have had every kind of trouble with all kinds of lightning arresters, and after having tried many experiments have come to the conclusion that whatever kind is used, the nearer it is placed to the trolley base the better."

Mr. H. W. Frund, Supt., Vincennes Electric Light and Power Company, Vincennes, Ind., March 19 and April 5, 1895 :—"We operate the alternating constant current system. We have many arresters which have seen more than two years of service, and at no time have we had any trouble with them. Our lamp account has been cut down wonderfully. We carried out your recommendations as to driving a one-inch pipe eight feet into the earth, after digging a hole four feet, into which we coiled one hundred feet of No. 4 copper wire, which was soldered to a brass plug screwed into the end of the pipe. We further protected the insulated wire above the earth by a $\frac{3}{4}''$ pipe, from 8″ below the surface to 8 feet above. We filled the hole up with crushed coke, commonly called "breeze," to within one foot of the surface. This is all expensive work, but we find it has improved our service in many ways, as well as reducing lamp bills. We have connected the arresters on the lines across loops and at points where lightning would otherwise have to chase around a length of extra wire."

Mr. E. J. Richards, Supt., Belt Electric Line Company, Lexington, Ky., writes August 20, 1895 :—"We have lost but one armature this season, that

being a car motor armature, and have had no trouble whatever with our generators from this cause. Neither have we lost any transformers or armatures in our lighting department. In our street railway department we placed line arresters about 800 to 1000 feet apart, grounding both to our rail system and to fire hydrants wherever convenient.

"In our lighting department the arresters are probably not located at such frequent intervals, as our circuits do not run in straight lines, but consist of a large number of short branches. We have placed a number of arresters on the main lines, especially near the power house and near the end of each branch. Where the branches were long and contained a number of transformers, we have placed a larger number of the arresters. There is no doubt at all but that the arresters have prevented a great deal of the trouble which we have had in previous years and we consider that our expenditure for these instruments has been amply repaid."

Mr. H. A. Wagner, Gen'l Supt., Missouri Electric Light and Power Company, St. Louis, Mo., September 25, 1895 :—"We consider that it is due almost entirely to your work and research in this field that it is now possible to successfully operate alternating current central stations with overhead wiring, where subject to severe electrical storms. Although now a thing of the past, the hours of anxiety which we used to experience during summer showers, and the large repair bills for burnt-out converters, were impressed on our minds too vividly to be forgotten. When we were forced to depend on indifferent lightning arresters placed at the station, there was rarely a lightning storm which did not seriously damage converters on the lines, and often cause trouble at the station as well.

"We now have about four hundred line arresters distributed over our lines, and for the past three years, since having most of them in use, we have cared as little about lightning as does a gas company. We have never had a suspicion of lightning discharge in our station during this time, and the number of converters burnt out by lightning discharge could probably be counted on the fingers of two hands. With properly insulated apparatus and lines, the protection offered by good line arresters is all that could be asked for, provided a liberal number be used, of a form requiring comparatively low striking E. M. F., and with no moving parts requiring inspection.

"We at first made it a point to inspect our arresters at regular and frequent intervals, but it was found so apparently unnecessary that the inspection was discontinued, and during the last two years practically none of them have been looked at. Our lighting territory has been considerably enlarged since we first began to use line arresters, and were we now compelled to operate without them, with our approximately 2000 miles of overhead wire, it would, without any doubt, be impossible to give satisfactory or continuous service during the summer months.

"Our system consists of a complete net work of feeders and mains, two of these feeders being ten miles long, and several over five. No service connections are made from any of the feeders, and we therefore find an arrester necessary only at each end of each feeder for its protection, one being in the station. Along the mains, they are so placed that no transformer shall be over one-quarter of a mile from an arrester ; in most cases the distances are shorter. Ground connections are usually made with copper wire, attached to one and one-half-inch iron pipe, driven deep into the ground and surrounded with crushed coke. Although the greater part of our system is operated at 1200 volts, we have several suburban circuits operating at 4800 volts, with step-up transformers. These circuits are naturally the most exposed, but the line arresters afford ample protection."

Mr. Paul Winsor, Assistant General Manager, West End Street Railway Company, Boston, Mass., August 22, 1895 :—"We have had very little ex-

perience with lightning; that is, we have had so little trouble from lightning that we have not paid much attention to the subject. Most of our generators are of the toothed armature type, and with these we have had absolutely no trouble from lightning. We have a smaller station, however, in which are surface-wound armatures, generators that have been in since we first started, resting on timber foundations. This year we are running this plant all summer and during lightning storms, but we have had so few storms that our freedom from trouble shows nothing. Previously, this plant has been run but little in summer, and has generally been shut down during thunder storms, but we have lost a number of armatures at this station.

"We have no line lightning arresters anywhere in the system except at the underground cable terminals. On these we put one lightning arrester at the pole terminal. Our stations all have lightning arresters on the generators, one at each generator. At the Allison plant, where we have surface-wound armatures, we have lightning arresters and kicking coils on both feeders and generators. They are all in good condition, but have not saved us from lightning at this station.

"All our cars are fitted with lightning arresters without kicking coils, and we have lost practically no armatures on cars from lightning. I recollect two or three cases where armatures were lost during lightning storms, but there is no proof that the loss was the result of lightning. Except at night our lines are well provided with lightning arresters, as from 5.30 in the morning to 12.30 at night we have from four to eight hundred cars with lightning arresters on the wire. Outside of these hours there are about ten cars on the wire. You will see from the above that our trouble from lightning has been so little that we have paid but little attention to the subject. The trouble at Allston was easily gotten over by shutting the station down, which we could do at any time during the thunder storm season by raising the voltage at the other stations 10 to 20 volts."

The above letter is especially interesting to me for two reasons; first, it sustains the general impression that surface wound armatures are more sensitive to lightning discharges than toothed armatures; and second, that in a large city like Boston so little trouble has been experienced from lightning that no special attention has been paid to the subject. It is generally conceded that large cities are less liable to disturbances from lightning than country or suburban districts. At the same time it does not follow that all large cities are free from lightning, or that small towns are to be considered especially subject to lightning storms.

For example, large cities such as Brooklyn, Philadelphia, Chicago, Pittsburg, St. Louis, and others, are unquestionably subject to severe thunder storms, while New York and Boston seem to be comparatively free, although situated in a section of country subject to thunder storms. There are, however, smaller towns, such as Bar Harbor, to my certain knowledge, and no doubt others, where lightning is rare. In Bangor, not far distant from Bar Harbor, lightning storms are up to the average for New England. It seems, therefore, a question whether the absence of thunder storms in large cities may not be quite as much due to the geographical situation as to the fact that the particular locality is a thickly settled district, with tall buildings, chimneys, steeples, etc., etc.

The feature which is at once prominent in these letters is the general use of line arresters, distributed at more or less frequent intervals, and it is conceded that these have largely reduced damage from lightning. There are plants, however, which suffer damage though well provided with line arresters. In view of the fact that a large majority of plants provided with line arresters are well protected, I am inclined to believe that the exceptions are due to local conditions, such as poor soil, absence of precipitation during thunder storms, long and circuitous

ground connections, original defective insulation and deteriorated insulation. The latter is not an uncommon occurrence with railway motors, and in this case is more often due to overheating.

The methods of grounding line arresters are somewhat varied, but nearly all resemble that shown on this page. One plant mentions the use of the overhead grounded wire. It is remarkable to note, as I have frequently had occasion to do, how many of the smaller and less prosperous plants still cling to the station arrester as their only protection. It would seem as though these, of all plants, could least afford to even temporarily lose the services of any part of their apparatus. The smaller concerns apparently deem it an extravagance to invest in apparatus which does not immediately effect an increase in earning capacity, and the lightning arrester, not being in itself a dividend earning device, is shunned as an extravagance. A small plant not long ago lost several transformers by lightning in a single storm. They were returned for repairs and by letter the local company begged for credit on two station arresters which they said they had never used and desired to return. They had no line arresters at all.

Lightning has been one of the important factors tending to improve the insulation of electrical apparatus. In past years insulation has been applied with reference only to the normal voltage of the circuit. To-day a broad margin of safety is required, the best grades of apparatus being tested before they are placed in service with a voltage from three to five times the normal. Apparatus thus insulated and protected with line arresters may, in general, be considered proof against ordinary lightning discharges. However, even with the best of care, deterioration is liable to occur through overheating, dampness and rough handling. Deteriorated insulation is always liable to damage from lightning.

Many of the operating companies are now doing their own repair work. Few of these, however, are provided with high voltage testing instruments, so that repair parts are frequently placed in service with an indefinite insulation. The repaired parts are capable of standing the normal voltage of the circuit, but when lightning occurs the apparatus is damaged, together with the credit of any lightning arrester which

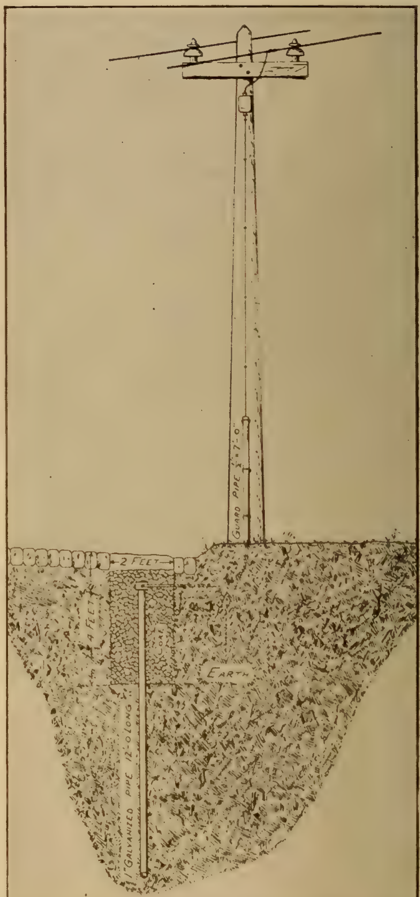


DIAGRAM SHOWING METHOD OF GROUNDING LINE ARRESTERS.

may happen to be in the neighbourhood. Testing instruments are made in a simple and compact form, and are now used in some of the larger plants. It will probably not be long before they are more generally adopted as a part of the repair shop equipment.

Reputable manufacturing companies do not hesitate to guarantee their

labour and material; the purchaser is, however, considered responsible for the proper maintenance of his apparatus. A few manufacturers make a practice of guaranteeing converters against lightning for a period of two years, but this is, of course, nothing more than a piece of insurance business. The guarantee does not protect the apparatus against lightning or light the lamps when the converter is burned out. A guarantee of this kind may sound attractive to the purchaser, and so long as the mere cost of repairs is the chief item of expense, consequent upon damage from lightning, the practice is, no doubt, a good one from the manufacturer's standpoint. The more general practice, however, with modern plants is to install lightning arresters, the main object being to protect the apparatus and thereby maintain an uninterrupted service.

The problem of protecting electric circuits against lightning divides itself under the following headings :—

Alternating current lighting circuits,

Direct current circuits up to 600 volts,

Arc circuits,

Power circuits,

Telephone, telegraph and switch and signal circuits.

I will consider each one of these with reference to current practice and endeavour to touch on points not mentioned by my correspondents.

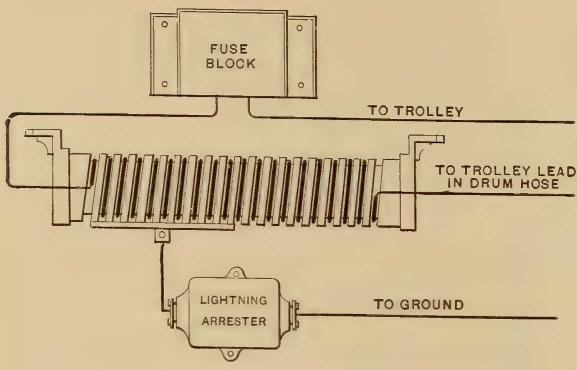
Alternating Current Lighting Circuits.—Station arresters are still to a large extent placed on the face of the switchboard—a custom and relic of earlier days. In some instances they are placed on the back of the board and in a few cases immediately outside of the building. Modern lightning arresters should not form a part of the switchboard apparatus; they should be placed back of the board, and in large plants are preferably located in a separate lightning arrester house or room. When thus placed out of sight, the line type of arrester is generally installed, this being electrically the same as the station type and considerably cheaper. Ground connection is made to a large, tinned, copper plate, buried in permanently damp earth directly under the arresters, the plate being covered, both above and below, with two feet of crushed coke or charcoal. Old castings or iron plates are sometimes used, but these are liable to rust away and be forgotten.

Gas pipes are avoided, but water pipes are frequently used, and, if in close proximity to the arresters, are to be recommended. Line arresters, usually of the double-pole type, are conveniently located on cross-arms, soldered joints being made both to the line and to the ground wires. Long leads have heretofore been provided with line arresters, but this practice has ceased, because linemen formed the slack wire into fancy choke coils instead of cutting it out.

In suburban districts, ground connections are made to small copper plates, to hydrants, old castings, in fact almost anything which may be found convenient in the respective localities. In city districts the simplest, and perhaps more common, method is to drive a galvanised iron pipe well down into damp earth. An improvement on this is to surround the upper portion of the pipe with crushed coke or charcoal, as illustrated on the opposite page. The ground wire is usually No. 4 copper, but larger sizes are often used. The writer recommends No. 4 copper, and suggests galvanised iron wire as being electrically quite as good as copper and considerably cheaper. In some instances idle day circuits are grounded in the station, but this practice is not altogether to be relied upon, for a ground at one end of a line will not protect converters and motors at the other end. In some instances where large units or banks of converters are to be protected, one or more choke coils are connected in each side of the circuit, with lightning arresters intervening, as shown in the lower diagram on the next page.

A single lightning arrester is connected at the junction of overhead wires with underground cables. In some cases, these are placed in the

sub-way; in other instances, on the last cross-arm, the location being governed by the conditions in each particular case. It would seem, however, as though the value of the property to be protected would warrant the installation of a series of choke coils and lightning arresters at each junction.

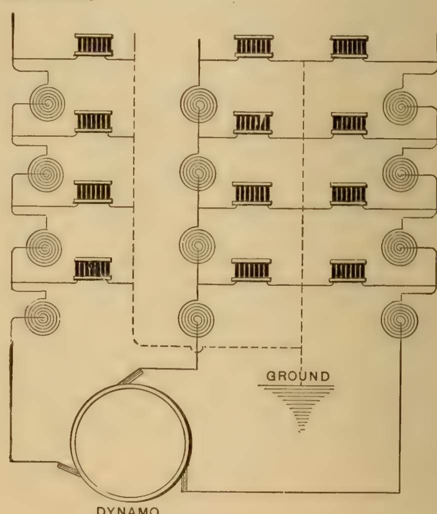


WIRING DIAGRAM FOR STREET CAR CHOKE COILS.

Direct Current Circuits up to 600 Volts.—The station spark gap arresters are installed in a manner similar to the station lightning arresters of an alternating current lighting plant. In railway power houses the tank arrester is not infrequently an additional feature. This device as a protection to railway generators has met with special favour, and has given excellent satisfaction wherever used. In some instances, particularly in the larger power houses, a tank arrester is supplied for each feeder. Where not more than 1500 ampères are delivered, one tank arrester will suffice for the entire station. Line arresters on railway circuits are grounded to a plate or pipe, and also to the rail. The latter method is preferred because it offers a direct shunt to the car motors.

In addition to the line arresters, each car is equipped with an arrester and a choke coil. The placing of an arrester on each car is an old and well established custom and, like all such customs, is difficult to change. The car arrester is supposed to "protect" the motor. The writer recommends placing all the arresters on the line, and choke coils on the cars. One lightning arrester does not protect any particular point; it is the entire lightning arrester installation which protects the entire plant and, consequently, every point in the plant.

The writer has recently designed an improved form of street car choke coil, which consists essentially of a coil of bare copper wire, wound on a channeled wooden spindle in such a manner that a copper strap may be brought into close proximity to about one-third of the convolutions of the coil. One terminal of the lightning arrester is then connected to the copper strap, the other to earth. In this manner advantage is taken of the tendency for disruptive discharges to spark at different points or at several points at the same time. The upper diagram on this page illustrates the electrical connections.



CHOKE COILS AND LIGHTNING ARRESTERS ON ONE END OF A 3-WIRE CIRCUIT.

Small direct-current motors are especially sensitive to lightning discharges and, when operated on trolley systems, should be protected with choke coils as well as lightning arresters. The usual practice, however,

is to protect each motor with a single lightning arrester. On lower voltage, direct-current circuits,—usually lighting circuits, — station and line arresters are installed in a manner already described. On three-wire circuits, three arresters are required, where one suffices on a trolley system.

Arc Circuits.—These are provided with station arresters, usually of the single-pole type, and these are grounded as already described. Line arresters have not until recently been extensively used, chiefly on account of the high tension and consequent danger of permanently grounding the line. Another reason for the limited use of line arresters on these circuits is due to the fact that the dynamo is practically the only piece of apparatus requiring protection, and also to the old impression that one lightning arrester will "protect." The lamps are only occasionally damaged. It is very probable that the series coils of the arc lamps tend to dampen the oscillations, and to this the writer attributes the fact that arc circuits are much less liable to damage from lightning than constant-potential circuits.

Summing up the above three headings under one general heading, namely, the protection of widely distributed apparatus, such as lighting and street railway circuits, it may be stated that line arresters are becoming more and more extensively used, and, in the opinion of the writer, they form the only practical method of protecting this class of electric circuits.

Power Transmission Circuits. — These, in distinction from railway and other power distribution circuits, require protection at the extremities only, and the general practice is to bank lightning arresters at these points. Where high potentials are used, arresters are connected in series to prevent the normal electro-motive force of the circuit from striking an arc. Arresters, thus connected in series, increase the resistance to earth for the lightning discharge ; it is therefore necessary to offset this increased resistance by the introduction of choke coils in the circuit between the arresters and the generator or motor, thereby opposing the passage of lightning discharges toward the generator or motor. The general arrangement of coils and arresters for this purpose is shown in Fig. 3.

For voltages up to 3000 volts, four coils are connected in each side of the circuit and at each end, with lightning arresters intervening. For higher voltages, the number of lightning arresters in series may or may not have to be increased, according to the possible output of the generator under conditions of short circuit and also according to the arrangement and use of raising and lowering transformers. Usually each case requires a special arrangement of coils and arresters. The apparatus is conveniently located in a small outhouse and with special reference to rich damp soil for the earth plate. Clay, sand and gravel, even though wet, make but a poor ground. A number of power plants, protected as above described, are operating with entire satisfaction.

The only instances known to the writer in which this method of protection has failed were, in one case, due to a single and direct lightning discharge striking twenty consecutive poles and hurling portions of these a distance of 150 feet, in which case one generator coil was burned out. One or two other instances occurred in the spring of 1895, in which cases the trouble was attributed to deterioration of the insulation in the foundation of the generator during the winter season.

Telephone, Telegraph and Switch and Signal Circuits.—These are provided with spark gap arresters at points where protection is desired, but I am not aware that any effort has been made toward a systematic installation of line arresters. Further, the instruments to be protected are not insulated with reference to lightning or any particular margin of safety. With a better grade of insulation and with line arresters distributed at frequent intervals, it is probable that damage from lightning on these circuits could be almost, if not entirely eliminated. Mr. A. S. Brown, Electrical

Engineer of the Western Union Telegraph Company, New York, on August 15, 1885, wrote :—

"The damage to telegraph instruments cannot be said to be serious in view of the great number of such instruments exposed. We are using for lightning protection two brass plates separated by strips of perforated mica. We find them satisfactory in the main ; their chief defect is their liability to ground the wire after a discharge. Our instruments are everywhere protected by such arresters. Instruments are not insulated at all with respect to lightning, but only with respect to normal E. M. F."

Where relays are used a peculiar difficulty occurs in connection with the platinum contact points. A static discharge, be it ever so small, has a tendency to stick these points together as though welded by the heat of the discharge. This is not a matter of serious damage to the instruments, but rather of interruption to the service. My attention having been called to this difficulty, I made a careful study of the phenomenon, and during a series of experiments last winter succeeded in forming a composition of metal, which, when made into contact points, refused to stick together. Steps are now being taken to apply this composition in the construction of relay contact points.

Summary.—Electric plants, feeding into widely distributed apparatus, such as converters and motors, are best protected by means of line arresters distributed at frequent intervals over the system. In suburban districts four to the mile of wire are recommended ; in city districts two may suffice. Where banks of converters or important units are concerned, four choke coils, with four lightning arresters intervening, are recommended. In railway power houses the tank arrester is considered an excellent protection to the generators. A choke coil and lightning arrester are usually placed on each car.

For power transmission circuits, where the points to be protected are situated at the extremities of the system, line arresters are not used. The generators and motors, or raising and lowering transformers, are protected by a proper installation of choke coils and lightning arresters at the points where protection is desired. Short straight connections to earth, good grounds and an occasional inspection of the lightning arrester installation with reference to broken wires, will repay the operating plant more than is commonly supposed.

SOME RECENT DEPARTURES IN STEAM ENGINE PISTON CONSTRUCTION.

By Professor John E. Sweet.

THERE are few details in any machine that have received so much thought ; which have appeared in so many forms ; in which new schemes have promised so well and ended so ignominiously, and where what seemed to be right was wrong, as the pistons of steam engines.

From the hemp-packed pistons, used by the masters of a hundred years ago, to the latest forms, the discarded experiments would fill a field and the inventors make a regiment, the bulk being some device for pushing elastic rings against the surface of the cylinder ; some arrangement to prevent the leaking of the steam past the joints in the rings ; and, in many cases, some scheme for carrying the piston in some sort of a shoe.

Aside from the question of preventing the escape of steam, the mechanical

construction of the body of the piston has been tried in a multitude of forms, and this, in itself, is a study. If made of one piece, there is nothing to get

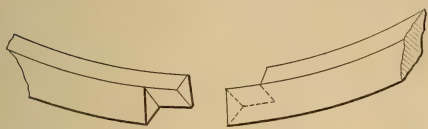


FIG. 1.

FIG. 2.

loose unless the piston itself leaves the rod, but a single casting calls for snap rings, or rings depending on their own elasticity for a fit to the walls of the cylinder, and, too, of such elasticity as to spring over the outside of the piston and snap into the grooves turned to receive them.

This system is used extensively, not because the makers believe it to be right or all that can be desired, but because there is scarcely any more objection to it than to most of the others ; it is cheap ; it permits the use of a piston cast in one piece ; and the buyer accepts it.

The reasons why the snap ring falls short of perfection are quite numerous.

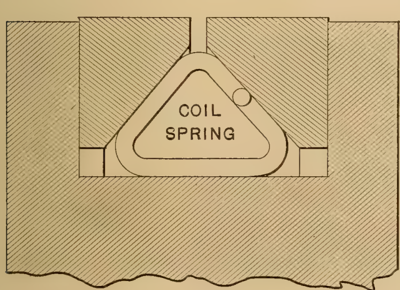


FIG. 4.

The lack of a steam joint where the ends meet is one. This would be overcome by having the joint at the bottom in the case of a horizontal cylinder, if the metal outside the ring be left full size, and the ring set back so as not to overrun into the counterbore; but they should always overrun. Lapping the joint in the ordinary way does not prevent the steam from passing, and besides, as a usual thing, when the ring overruns the counterbore, such rings are blown in and have so little initial tension that when they fly out the noise is not heard. If too stiff, or with too much initial tension, they soon wear out, and if too weak they are liable to be locked in by gummy oil or any slight abrasion of the piston.

Two forms of joint that completely cut off the steam, both from leaking past the piston and behind the rings,

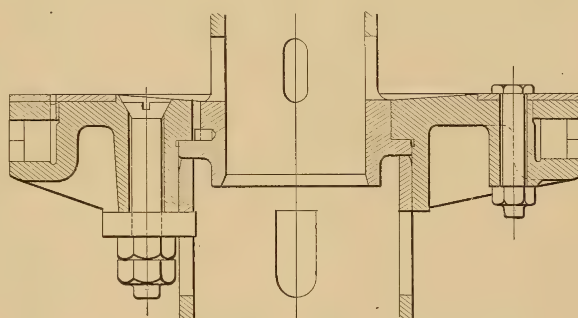


FIG. 3. SECTION OF THE WILLANS PISTON.

are shown in Figs. 1 and 2, but if of cast-iron, which, for wear, is the best of all material, the ends are liable to break off and become elements of danger. Pieces riveted on over the joint are but little better, as the rings are weakened to the extent of the rivet holes.

The foregoing gives a hint at the various difficulties encountered in the endeavour to make a perfect piston, and is intended to serve as an introduction to the following description of some of the recent schemes to improve on this single steam engine detail.

Some years ago a marked change was made by the writer in a reversal of the usual practice, that is, instead of maintaining a pressure on the rings to keep them pressing against the walls of the cylinder, the rings were made to

exert a much greater force out and were then limited to prevent their crowding beyond a perfect fit, and left free to compress to meet the condition of a

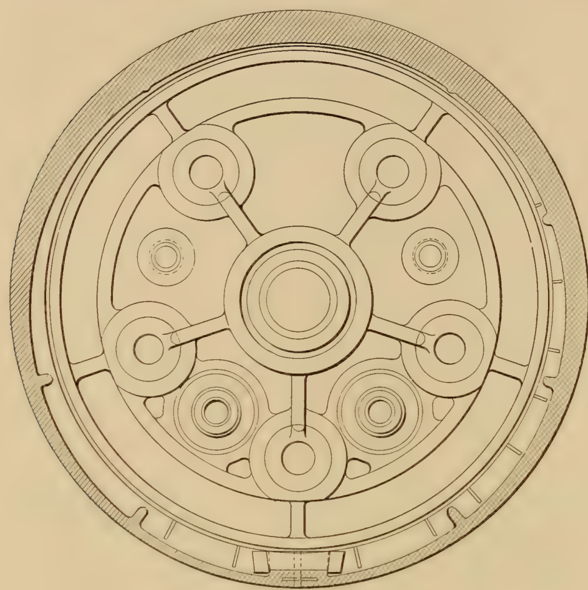


FIG. 5.

change in size by a change in temperature.

Whatever defect this feature has shown has been due to construction notice was made by Peter William Willans and employed in his wonderful engine, and consists of two features, shown in Fig. 3. The rings used consist of an eccentric bull ring, one inch wide, surrounded by two very thin rings outside, each ½-inch wide, with the bull ring cut in its thinnest part, and the two outside rings cut and so placed that they cover the joint in the bull ring, and the joints in the outside rings mismatched and pinned so that there is nothing to break and the steam leak is completely cut off. So far, the ring is, in form, very like one of the oldest forms, differing only in having the bull ring eccentric and forcing out the outer rings by its own tension.

The most marked departure from common practice is in making the follower of sheet metal and so securing it to the body of the piston that by the pressure of the steam the sheet metal springs and grips the rings fast as they pass through the cylinder, in effect something like the

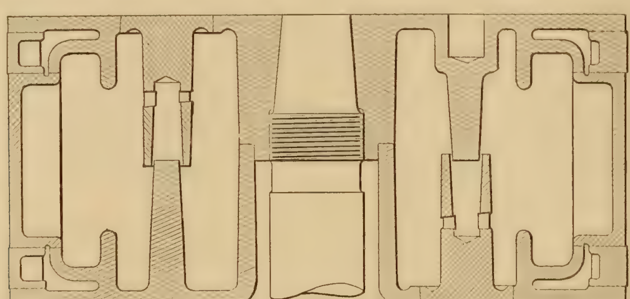


FIG. 6.

and not to the principle of limited expansion. Improvement in this ring as originally constructed is illustrated in connection with the last plan that is to be described.

One of the most radical changes following this that has come to the writer's limited expansion before mentioned.

From the fact that the engine for which the limited expansion rings were designed was a horizontal one and the Willans is a vertical one, certain features, applicable to the one, are not applicable to the other, and the Willans rings, in-

stead of having great initial tension, have only enough to hold them in contact with the cylinder, and as the engine is single-acting they are not called upon to act but in one direction, or half the time, so that the rings, on the return stroke, glide through the cylinder with very little pressure. To prevent the blowing in of the rings while overlapping the counterbore, steam is let in back of them through very small holes, so that probably the pressure does not exceed one-fourth the steam chest pressure.

For the vertical single-acting engine it is believed by the writer that this is the best piston supplied by any builder. Where a similar arrangement is used without the grip, the rings wear loose in the grooves, and the steam packing, putting on more pressure at the commencement of the stroke, wears the cylinder conical.

Accurate measurements, taken after four years of constant service, show that the wear does not exceed two or three thousandths of an inch, at most. This, however, is under the most favourable conditions, as both cylinders and rings were of the excessively hard iron always used by the Willans Company.

A form of piston ring which has recently come to the writer's notice, introduced in England, is shown in Fig. 4. It covers one of the Willans principles, though it accomplishes its result in a different way. It will be seen that the spring not only forces the two parts of the ring against the walls of the cylinder, but holds them in close contact with the two walls of the groove as well. With some positive cut-off at the joint, something like that shown in Fig. 1, excellent results may reasonably be expected from this arrangement.

E. J. Armstrong has introduced in the Ames engine a feature that is original with him, so far as known to the writer, and consists in making a hollow piston in one casting, supporting the core on five or six horns, leaving holes in the periphery of the piston between the rings, differing from pistons long used by others only in this that others plug the core holes, while Mr. Armstrong leaves them open.

The theory is that steam, leaking past the first ring, will soon fill the inside of the piston and naturally tend to bring the pressure up to the mean effective pressure, but, at the same time, the steam inside has the same chance

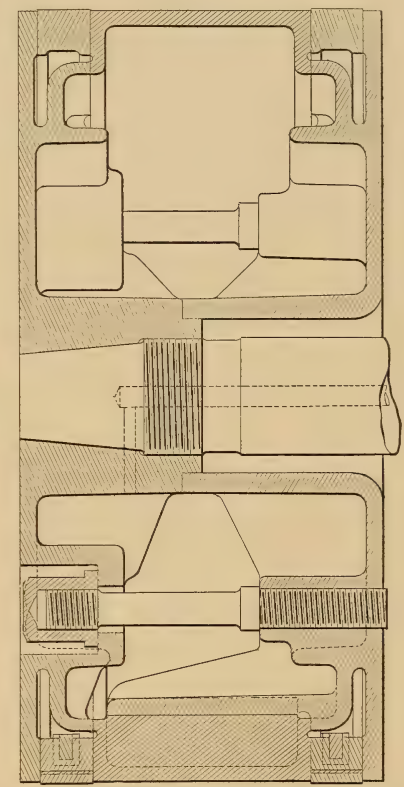


FIG. 7.

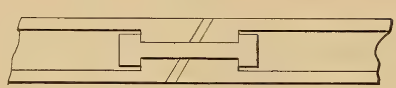


FIG. 8.

to leak past the second ring and so let the pressure down to half way between the mean effective pressure and exhaust. It is assumed, and with reason, that the pressure is about one-fourth the boiler pressure, and this pressure is used to force out the piston rings by passing through small holes from the inside of piston to inside of rings.

In Figs. 5, 6, 7, 8 and 9 are shown combined three somewhat novel features, the first being an adaptation of the Willans principle to the piston of a double-acting horizontal engine, in which a cored casting takes the place of the separate sheet metal plates. This reduces the number of pieces, and whatever objection there may be, the outer piece cannot become detached or loose,—an improvement not perhaps sufficient to justify the piracy.

A second feature is that the two sides are of equal width all the way around, and the central portion is eccentric, possessing the merits of an eccentric ring without its objectionable feature. To secure the full advantages of the eccentric principle the flanges are cut with a hack saw at frequent intervals, as shown in Fig. 5; in fact, by sawing to the proper depth the true result can be obtained, which is not quite possible with a true eccentric ring. The rings are locked with a T-headed tie to secure the limited expansion.

The third feature, not directly in line with the foregoing, is a safety device to supply relief in case of an excess of water. Taper plugs, as shown in Fig. 6, are pressed into taper holes with sufficient force to hold them against any legitimate pressure that may come upon them, but not so tight but what water will drive them back before the cylinder heads would be broken. This furnishes a relief equal to the internal capacity of the piston. This does not render it necessary to shut down the engine, as no harm comes from continuing the run except the loss due to clearance.

To secure the relief plugs from tumbling about inside the piston when driven from their seats, the taper sockets at the back are driven onto the taper pins cast on the opposite side of the piston, and in order that the engineer may know that the relief plugs have been driven out, a hole is drilled from the cavity in the piston to the centre of the piston rod connecting with a hole in the centre of the rod that ends at the crosshead, through which steam will issue at each revolution.

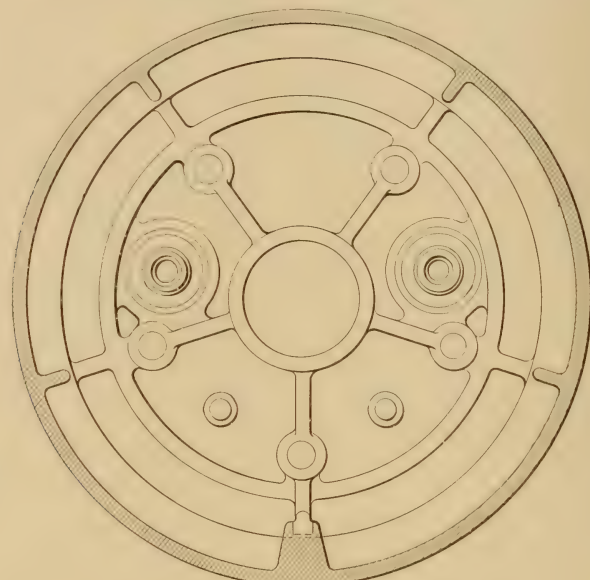


FIG. 9.

Other special details of construction are shown. Long studs in place of short cap screws, with the body turned down to the bottom of the thread, and cap nuts to prevent steam leak, extremely thin castings with many thin wide stiffening ribs, etc.

MODERN SHIPBUILDING TOOLS.

By J Arthur Gray.

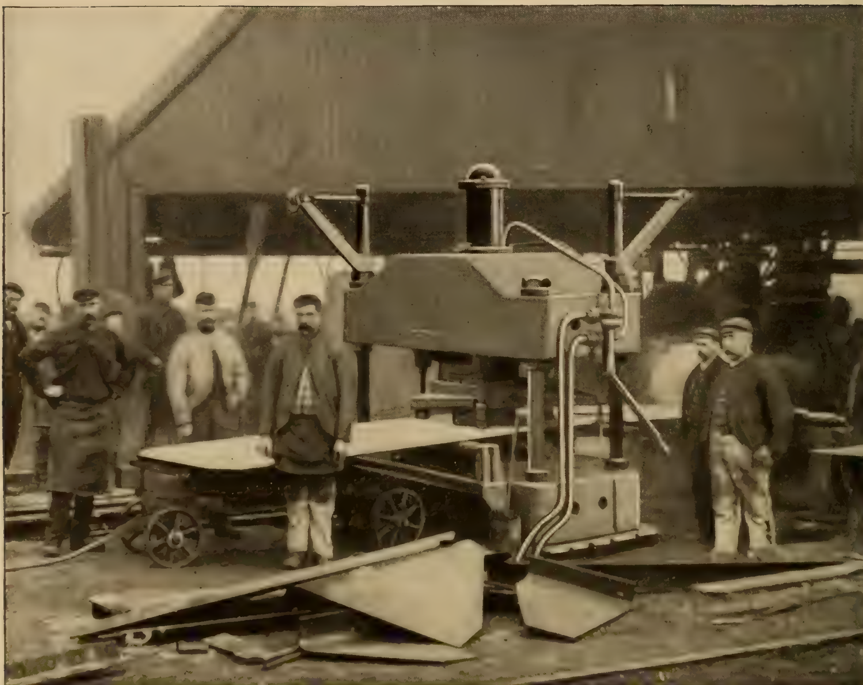
(Concluded from page 338.)

SO many punching machines are required in a shipyard that it is important to notice their various forms and merits. A description has already been given of the early form of this machine as originally used for making holes in boiler plates. When larger and stronger perforators became necessary, the most convenient form was found to be that in which the punch slide was moved up and down by an eccentric pin on the end of a main shaft. This form had the advantage of occupying less room than the old lever machine, and for many years it was the favourite design. It had one fault, tolerable enough in slow-going days, but quite inadmissible in the present go-a head times. After a hole was pierced, its punch lifted with the same slow deliberation with which it had descended. Much time was thus wasted. The plate could not be shifted for a fresh hole until the punch had been withdrawn. We all know the action of a modern slotting machine. By elliptical wheels, or some other device, the tool is made to descend at the requisite slow cutting speed; but when it has reached the bottom of its stroke, it is lifted quickly, and then resumes its slow descent.

An old-fashioned slotter, the slide of which rose as slowly as it descended, would not be tolerated in any well-regulated machine shop now-a days. But so it was with the eccentric punching machine. Its average speed of working might be accelerated a little, and its stroke lengthened so as to mitigate the evil as much as possible, but still its punch lifted as slowly as it descended, and this was so out of harmony with modern progressive ideas, that it became insupportable to every yard manager who had any push in his nature. It was endured only as long as it was considered irremediable.

But there were some whose mind reverted to the old lever machine with its variable cam, that gave the punch a rapid up-stroke, and there is good reason to believe that it was Mr. Cameron, of Manchester, who set to work to design a machine that would embody the principle of the lever and cam, and yet possess a form and strength that would answer modern requirements. He succeeded in making the modern lever and cam punching machine, and was speedily imitated by other makers, some of whom have introduced further improvements of their own.

The levers are now made quite short and massive, the longer and shorter arms are in the relation of something like 2 to 1; but as they work the slides from above, the form admits of a very deep gullet or gap to fit it for taking in wide plates. The new design is even more compact than the eccentric machine, and its superiority is, in every respect, beyond dispute. As first made, it was found liable to excessive wear between cam and lever, the action between these members being a rubbing one which was not easily lubricated. But this defect has been remedied, and now the machine can be seen at work, often punching holes at the rate of 40



A HYDRAULIC PUNCHING MACHINE, BUILT BY MESSRS. HUGH SMITH & CO., GLASGOW, SCOTLAND.

or 50 per minute, instead of 16 or 20 by the eccentric machine. It is made with gaps up to 42 inches depth, which enables it to punch holes in the centre of a plate 7 feet wide. In its larger sizes it punches with apparently great ease, plates up to 1½ inch in thickness, and that is somewhat thicker than any plate ever required in ships for merchant service. It is true that deck plates in the navy are now used up to 3 and 4 inches in thickness, but it has not yet been deemed advisable to make the holes in plates of such thickness by means of the punch.

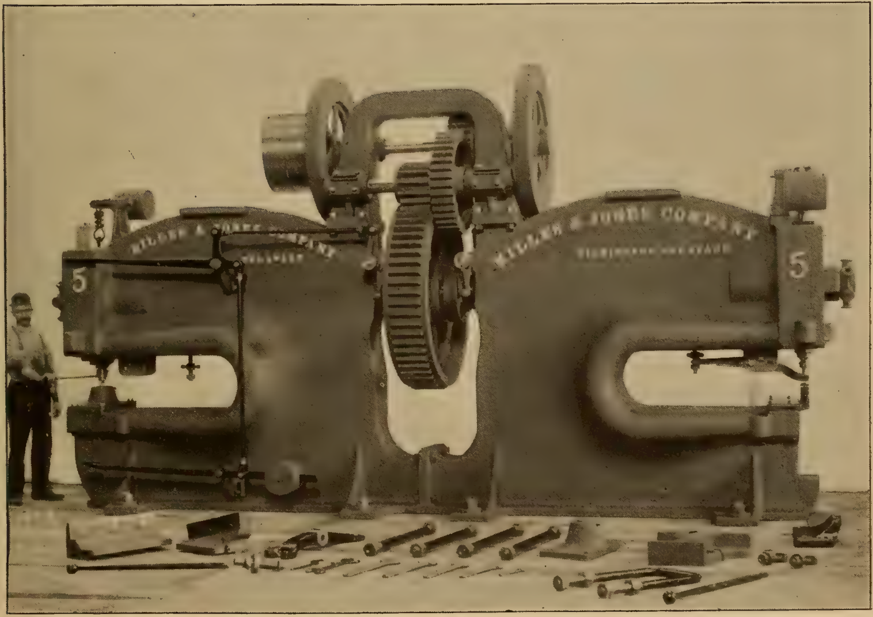
There are limits to the smallness of hole that may with safety be attempted by a punch. It is not safe to try to punch holes smaller in diameter than the thickness of the plate. It is not yet possible to obtain steel of such quality in the form of a punch, that it will perforate a cold steel plate that is much thicker than its own diameter. Some exceptional cases have been recorded. The writer has seen a punch ⅞ in. in diameter, of excellent steel, carefully tempered, pierce a few holes in an 1⅛ in. plate of wrought iron. At the fourth hole, however, the punch bent a little, and showed signs of failure. So it was not thought prudent to attempt any more. It may be estimated that the punch in this case had to exert a pressure of about 78 tons at each punching, and that is equivalent to about 130 tons per square inch of sectional area. To attempt, therefore, to punch a 1½ inch hole through a 3-inch plate would certainly result in crushing the punch, for it would have to bear a total pressure of at least 360 tons, or about 200 tons per square inch of section of the punch, and that is twice as much as the best cast steel has been found capable of sustaining without compression to destruction.

The pressure required to be borne might vary considerably, according to the conditions of punch and die; it

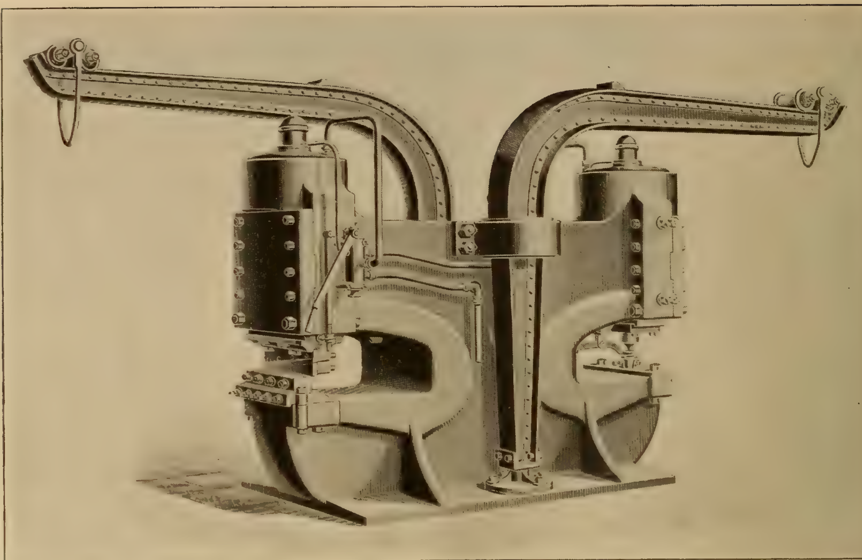
might, indeed, be much greater if the plate were of a hard character. In Messrs. Armstrong's yard, at Elswick, there is a machine, made by a Glasgow firm, which punches and shears steel plates up to 2 inches in thickness. But the punch, in such cases, is never less than 2 inches diameter. Whether it will ever be considered advisable to make a larger machine, capable of piercing cold steel plate up to 3 or 4 inches in thickness is very questionable. It is unsafe to prophesy. That we should be able to punch and shear 2 inch steel plates cold, would not have been believed 50 years ago, and who would venture to say that greater things may not be done in the near future? The machines can be made, steam driven or by hydraulic pressure,—there is no doubt of that. But at the present times it seems inexpedient. It seems in every way preferable to bring such heavy plates under a powerful drilling machine, by which holes of any diameter may be made.

The large lever punching machines as now made seem to leave little to be desired. They are sometimes fitted with "twin" punches at one end, for punching two holes at each stroke. These can be set obliquely for zig-zag riveting or in line with each other, and each punch has a separate stop motion, so that the attendant can suspend the action of one punch at discretion. The larger machines are also fitted with cranes at each end, having jibs about 15 feet in length, and thus very long plates can be carried up while under the punching or shearing operations. Usually a strong iron frame-work on top of the machine carries the cranes, and the same framework serves to carry guide pulleys when it is desired to drive by a belt. Thus the belting can be carried to the machine clear overhead and out of the way of the crane jibs, which can swing a full half-circle at each end. But pulleys on this machine are seldom adopted now, the preference being wisely given to the separate motor attached to the machine. This is referred to farther on.

In some few cases the main shaft of the lever machine is prolonged, and has an eccentric pin formed on its end. This end forms part of an additional



A DOUBLE PUNCHING MACHINE, BUILT BY THE HILLES & JONES CO., WILMINGTON, DEL., U. S. A.



A DOUBLE HYDRAULIC PUNCH AND SHEAR, BUILT BY THE MORGAN ENGINEERING CO., ALLIANCE, O., U. S. A.

punch or shear which adapts itself to a variety of work in a shipyard. It sometimes cuts out the notches from the edges of stringer plates or intercostal keelson plates where clearance gaps are required. It is also suited for cutting out manholes or limber holes. Another adaptation on one side is an angle iron shear which permits a bar to be passed through the machine, and, as there is a disengaging motion, the bar can be cut off at any part of its length. It cuts the bars on the flat, as all shears for ship's angles should. Those that cut with the heel of the angle down are of no use to the shipbuilder, however useful they may be for girder work where only straight angle bars are cut. This shearing arrangement falls in most agreeably with the design and purpose of the machine, and does not in the least interfere with other operations.

Before leaving this part of the subject, it may be mentioned that angle bars and beams are often most conveniently punched on a machine whose punch slides to and fro horizontally. Bars of angle steel, however large in section, are now cut by cold shears with as much ease as one would snip the end off a cigar. A special machine, designed for cutting angles on the flat, right and left hand, usually combines two horizontal punches. These do duty at each end of the machine, and can be worked independently.

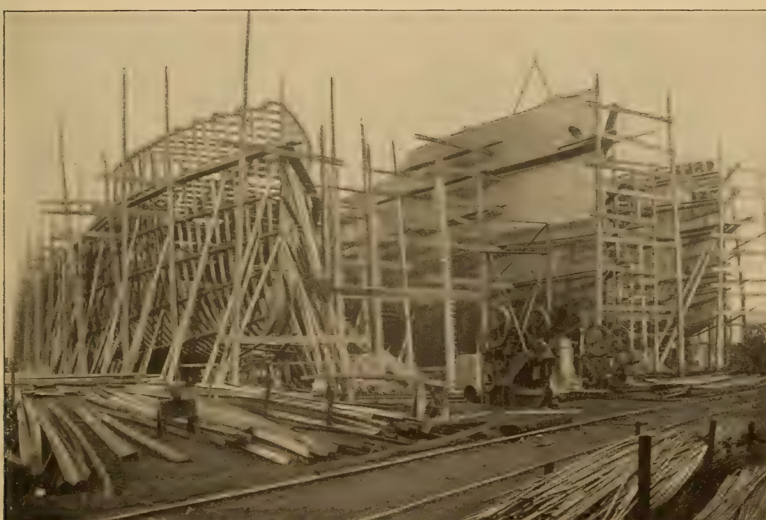
There is a useful section of steel which seems to present some difficulty to the shearing machine. That is the Z section. It serves the purpose of two angle bars, riveted together, and is lighter and cheaper. It would be quite easy to make a pair of shears for a given size of Z bar ; that has already been done ; but how to make a machine that is readily adaptable to all sizes of this section, remains as yet a hard nut for toolmakers to crack. For, in cutting such sections it is important that the bar should not be put out of its normal shape when cut by the shears.

It is bad economy to cut these cold, and then require to heat the ends in a fire in order to hammer the section back to its shape. It is much better to cut such sections by the cold saw, however slow it may be. The Z bars are cut at the steel works while hot by

a hot saw as they come from the rolls. But a hot saw is out of place in a shipyard.

The cold-sawing machine is a most useful tool for cutting a section of any kind to an exact line and at any required angle. It leaves a clean-cut end, well suited for a close-fitting joint. The machine resembles an ordinary circular saw table, but, of course, the saw revolves at a slow speed, and instead of the article to be cut being pushed against the saw, the article is firmly fixed to the table, and the saw moves forward by self-acting as well as by hand-feed gear. The saw is about ¼ inch thick at the periphery, and somewhat thinner towards its centre, so that it may clear itself freely in the cut. The feed can be varied, but on the average the saw advances through the bar at the rate of one inch per minute. Its slowness of cutting is its only defect. But it is cheaper to have a clean, smooth cut made exactly where wanted, at a slow rate, than to have to dress a rough-cut end by heating and hammering in the smithy, and afterwards chipping and filing. Band saws for cutting iron and steel have been in use for some time, but they have not, as a rule, been adopted in shipyards, though there are many operations in which they might be useful. They are machines greatly prized by locomotive engineers, and by gun-carriage makers for cutting out frames.

A most important tool is the beam-bending machine. In the early days of iron shipbuilding, the deck beams were heated, like the angle frames, in a long furnace, and the proper arching was imparted to them while hot. That was an expensive process. Various means were resorted to in order to give a camber to the beams while cold. For a long time a screw, with double purchase gear, was brought to bear upon them, and this was worked by hand, in much the same way as railway men give a set to the rails. This served the purpose fairly well for a time. But a squad of men were required to work the machine; and the work was labourious and the product irregular.



ON THE STOCKS.

Mr. Bennie, of Glasgow, saw that the work could be much better done by belt power, and he patented a machine that speedily took the place of the hand-worked tools. He gave a fixed stroke to his bending ram, and

adjusted the two bearing blocks by screws, so that beams of any breadth in section could be curved in it. The degree of pressure could be regulated by the same screws. This saved much hand labour. It saved also the need for skill on the part of the attendant, and the work was much more correctly done than was possible before. The beam-bending machine, worked by a separate motor or belt, is now to be seen in nearly every shipyard.

The tool next in importance, perhaps, is the plate-edge planing machine. Many good ships were built of iron before this machine was thought of. These earlier iron vessels had their plates put on simply with the rough edges as they came from the shears. When the plates were butted, end to end, it was not possible that their junction could be close at all points. Much dependence had to be placed on thorough caulking of the cover plates. And then the joints did not look well on the outside. They had not a tradesmanlike appearance.

This objection led to the planing of the butts or ends of the plates, and small machines were designed for this purpose. For a long time only the butts were planed while the other edges of the plate were left rough. But it was found that the planing machine made such trim and smooth edges that it became desirable to have planers long enough to smoothe the side edges as well. Now planing machines are made as long as the plates in use, that is, up to 30 feet in length.

It was natural that the first designs of such planers should be on the model of the engineer's planing machine. Although the work was fixed and the tool made to slide, the tool cut only one way, and had to be run back before it could make a fresh cut. Some genius saw that if the cutting tool could be quickly turned at the end of its stroke to face the other way, the machine might cut both ways in traversing. That saved much time, and rendered the two speeds of gear unnecessary,—the quick return as well as the slow advance. The machine was made so far self-acting that at the end of its stroke the slide itself actuated the reversing gear, and the man had simply to turn the tool and give the additional feed.

It was found, however, that on commencing to plane the rough edge of a plate, there were certain prominences that had to be reduced before a full continuous cut could be obtained. A labourer was sometimes stationed at the driving pulleys to reverse the machine on a sign from the planer hand ; but now that man's work, and much time, are saved by another arrangement. The planer attendant, who is carried along on the platform of the slide, has simply to press his foot upon a treadle in the middle of his platform,—the reversing bar is caught firmly by a friction lever, and the belts are thereby carried over to the reversing pulley at once. He takes down all prominent parts until the edge is straight enough for a full cut all the length of the plate ; then the reversing is done automatically at the end of the traverse.

Many other improvements in details have recently been effected on this machine. A few of these may be referred to. A ready mode of gripping and securing the plate was wanted ; so instead of holding the plate down by screws, there are now several small hydraulic rams which bring their pressure instantly to bear on the plate by simply turning on the pressure water. The machine has been so constructed that in many cases it can plane one end of the plate while the side edge is being operated on, and this end can be planed at right angles, or at more or less acuteness or obtuseness as may be required.

The saddles with the cutting tools are driven by steel screws of large diameter and coarse pitch, and these screws are embraced on the upper side by a long half-nut, carried by the slide. The long screws are supported and kept from sagging by troughs of cast iron, bored out smoothly, and exactly fitting the outer diameter of the screw, and the latter is so placed as to be quite

out of the way of the cuttings or anything else that might tend to injure it. Long crane jibs are sometimes attached to a large machine for lifting out and in the plates.

It need hardly be said that masts and spars are now made of steel plates, and in order to roll the plates into the requisite form, they are put through special rollers of suitable length and diameter. The top roller does not usually exceed 11 inches in diameter, and the machine is constructed so that the roller may be easily withdrawn from the inside of a tube which it may have bent around itself. The roller is drawn through one of the end housings.

Another machine of recent introduction is the mangle, or plate straightener. Most plates, as they come from the iron works, are more or less buckled or warped by unequal contraction in cooling. To take the warps out, it is necessary to roll the plate when cold. Many of these plates are wanted quite flat, for bulkheads, deck-houses, etc. They are therefore put through the flattening machine, as it is sometimes called. This consists, generally, of two standards with a number of rollers on two planes between,—usually seven altogether, three of which form the lower tier and four the upper one. The lower rollers are so geared that they all revolve in the same direction, and the top rollers are loose, and can all be moved up or down simultaneously to preserve their level.

When a plate is put through these rolls, it is subjected to a series of rolling undulations, resembling gentle corrugations while between the rollers. The reversing gear runs the plate to and fro while receiving this treatment, and the alternate bending, one way and then the other, takes all the buckles out of the plate, and it comes from the rolls quite a level plane. It can have a slight curve imparted to it, if necessary, by the two outer rollers of the top side, which are separately adjustable. This is sometimes wanted when the plates are to form deck covering.

Countersinking drills are required for rymering all the holes in the shell plates, and these are of various designs. But the best are those that are carried by radial arms. A number of these being fixed on a wall, or line of pillows, at intervals of from 7 to 10 feet, according to the length of the arm. By this system the heavy plates now in vogue can lie immovably on a suitable bench, and all the drills can be brought to bear on the punched holes. This saves the necessity for moving the plate to adjust each hole to a fixed drill. The cutting tools are not strictly drills; they are merely tapered wideners, making smooth and uniformly conical holes.

Another labour-saver which has recently come much into use is the bevelling machine, for altering the ordinary angle of angle-bars to a more acute or more obtuse angle. Many of the angle-bars require such treatment, particularly in those frames situated near the stem or stern of the ship, as well as in the case of stringers and keelson bars. Such bars require a gradual closing or opening from one extremity to the other. The bars used to be treated by hand-hammering, and frequently they had to be heated more than once or twice before the proper set could be imparted to them. Some skill on the part of the manipulators was necessary, and even then the bars were irregular along their sides, and would not lie close to the plates without some cold hammering that tended to break them in their position.

Messrs. Davis & Primrose, of Leith, a few years ago patented a machine for executing work of this kind. By means of this machine, which is usually portable on rails, the bar, as it comes from the furnace, is simply passed between certain bevelled rollers which are adjustable even while the bar is being rolled. And the machine gives the requisite "out-bevel" or "in-bevel" to Z bars as well as to L bars. An index on the machine enables the workman to alter the angle of the rollers as the bar passes through, and thus any degree of graduation can be applied. Besides economising labour, this produces far superior

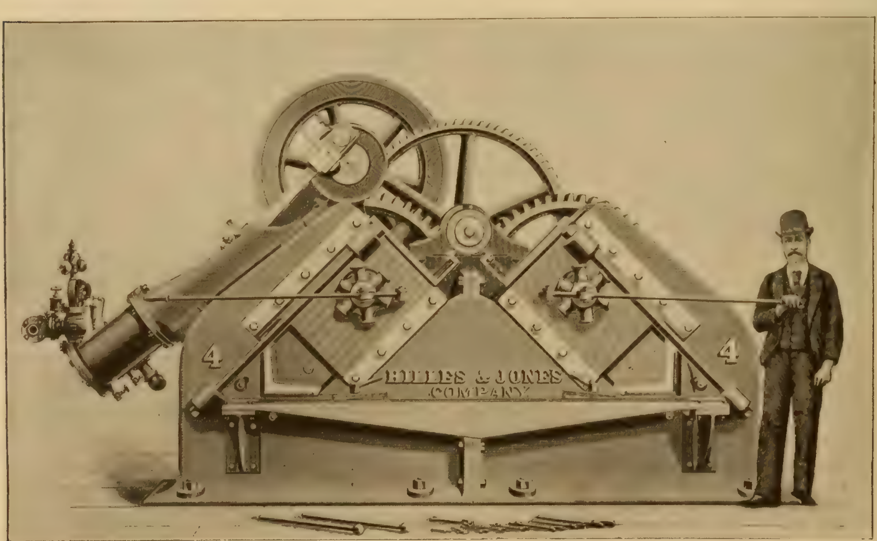
work. The hammered bar can never have the smooth and regular form of the machine-pressed bar.

All the machines just described may be said to be essential in this modern form, to the proper equipment of the steel-working department of a ship-building yard. These are the tools without which the business of ship-building cannot be carried on successfully. There are a few other iron-working machines found in yards where economy of labour and rapid production are pushed to extremes.

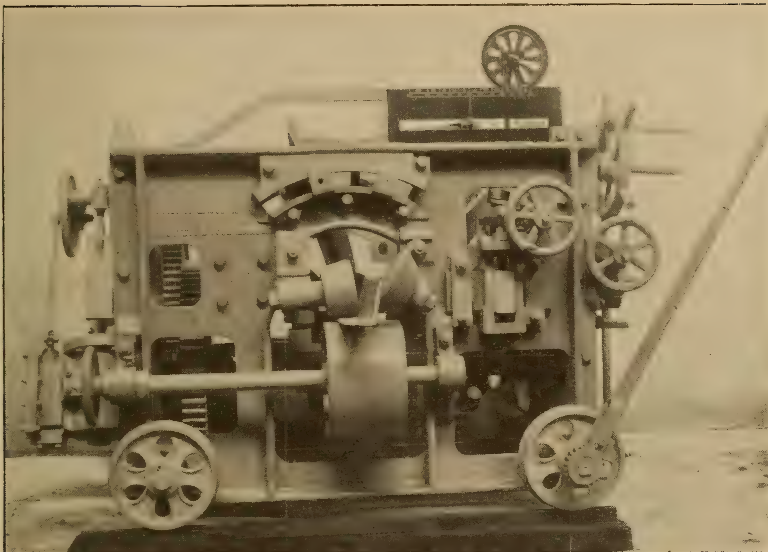
The steam hammer is not exclusively a shipyard tool, but in its smaller forms (up to 8 or 10 cwts.) it is almost indispensable in the smithy, for welding up the knees of beams, forging stanchions, and many other purposes in shipwork. The time seems to be at hand, however, when the steam hammer will have to make way for the hydraulic forging press. Hitherto such presses have only been used in large sizes for dealing with heavy forgings such as shafts, guns, and like masses made from heavy cast-steel ingots. For such purposes the forging press is undoubtedly superior to the steam hammer. The latter requires an immense foundation and anvil block. The shock of its impact makes the earth tremble for a considerable distance around, and imperils the stability of buildings in its neighbourhood. Moreover its compressive action on large masses is not so perfect as that of the hydraulic press.

Hammering is good enough for the surface, but it does not seem to thoroughly consolidate the heart of the forging. The forging press, on the other hand, is gentle in its descent, but it compresses the ingot most effectually to its core, and this is done noiselessly, and without the least shock or vibration. There is no reason, then, why small hydraulic forging presses should not be used for such light work as has hitherto been done by the 5 cwt. steam hammer. Nearly every yard now has its accumulator, and a small pipe is all that is necessary to convey the motive power.

A most useful tool, however, is the portable steam hammer for welding up stern and rudder frames. It has always been a most difficult and rather imperfect operation to unite these parts properly by hand hammers, and they are usually too broad to be accessible to the ordinary fixed steam hammer. Two large parts of a stern frame have usually to be heated *in situ*, while placed to-



A DOUBLE ANGLE IRON SHEAR, BUILT BY THE HILLES & JONES CO.



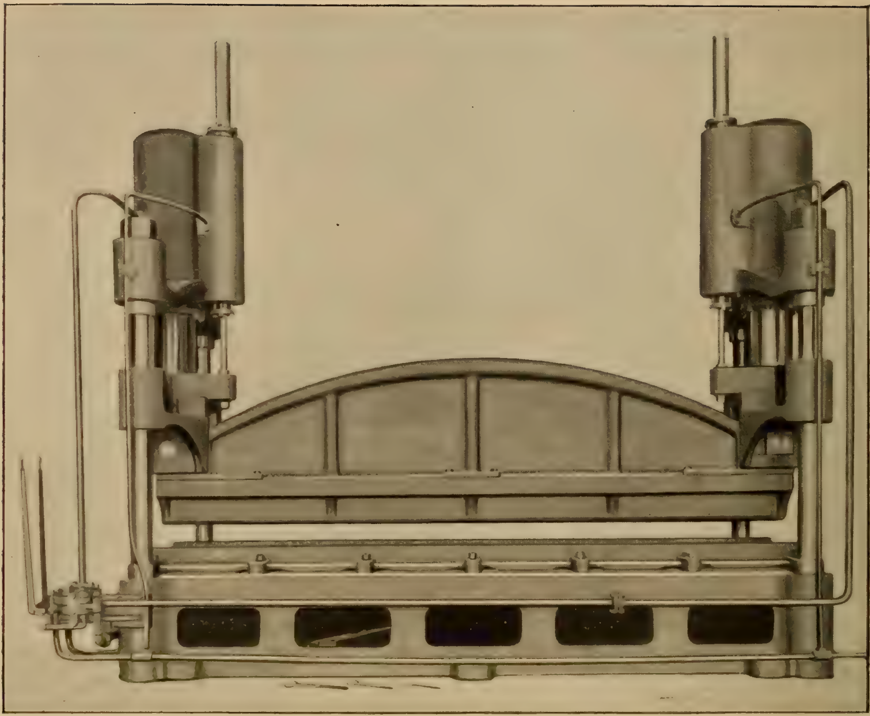
BEVELLING MACHINE FOR ANGLE IRON AND OTHER SECTIONS, BUILT BY MESSRS. DAVIS & PRIMROSE, LEITH, SCOTLAND.

gether in the position which they are to occupy when welded. They are heated at the parts of the junction in open fires. When brought up to a welding heat the fires have to be withdrawn quickly, and the piece called a "glut" is brought at a welding heat from another fire, and is hammered into the space where the joining takes place. This has usually been done by a heavy sledge hammer having three or more shanks, and handled by as many men. But by this mode the welding is very unreliable.

The hammer is much too light to make a solid weld, and the work is done at a great disadvantage, and with harassing labour. The portable steam hammer has altered all this. It resembles the ordinary smithy steam hammer, except that instead of the cylinder being attached to a fixed column, it is carried by a jib, like a crane, can be raised or lowered, swung around, or moved to and fro until it is exactly over the work, and by a few heavy blows the welding is done most effectually. The workman who manipulates the hammer and the racking gear is stationed at the base of the crane, quite out of the way.

This movable steam hammer has rendered the welding of stern frames and similar forgings quite an easy and satisfactory operation. It was first brought out by Messrs. Bennie, of Glasgow, and was first set to work on stern frames in the works of the Parkhead Forge Company of that city. The kind of work this hammer does could not easily be executed by a hydraulic press.

It now becomes necessary to say a few words on the use of hydraulic machinery in the shipyard. There are few good yards without a set of hydraulic pumps and an accumulator, whereby a store of water can always be had under a pressure of 1500 lbs. to 2 tons per square inch. Tweddell's patents are well-known as successful designs of hydraulic tools of all kinds, and have already been fully described in a previous number of this magazine. There are now many other good makers of hydraulic machinery. The pumps are generally worked from the line shafting, and these keep the load raised to the highest point so long as no water is being withdrawn from the accumulator. When the load is up there is no unnecessary expenditure of power, for



UNIVERSAL HYDRAULIC BENDING MACHINE FOR KEELS, DECK PLATES AND MISCELLANEOUS IRREGULAR PLATE WORK, BUILT BY MESSRS. BEMENT, MILES & CO., PHILADELPHIA, PA., U. S. A.

the pumps are stopped by automatic gear as soon as the load reaches a certain point. But the moment the highly pressed water is tapped, to work any of the machines, the load begins to descend and the pumps are set to work to maintain the elevation of the load.

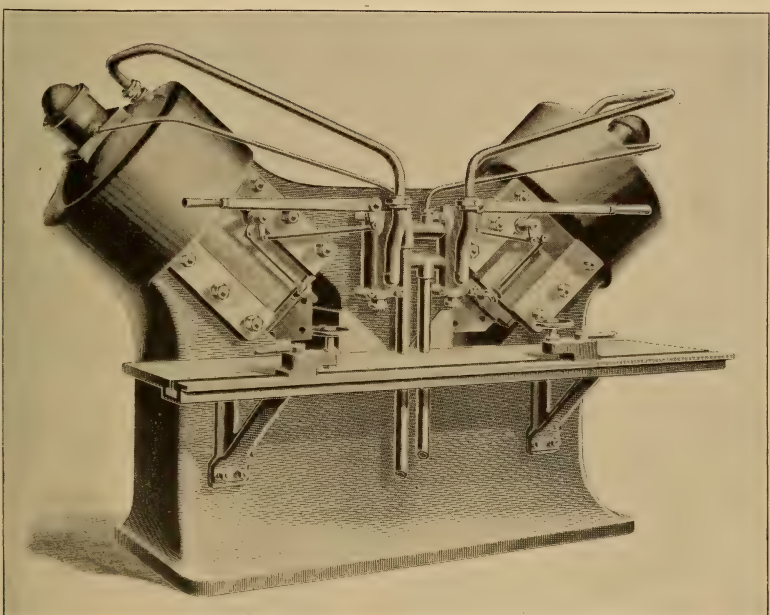
The accumulator is simply a reserve of force which can be drawn upon at any time, and it is important to have the pumps of sufficient capacity to keep the load up when all the machines which the pressure water drives are working at the same time. It is seldom, however, that all the hydraulic machines want to work at the same moment. If the demand is too exhaustive, it is not difficult to make arrangements that certain operations may be suspended until the claims upon the reservoir have abated.

The machine tools of modern construction that are worked most advantageously by pressure water are the keel-plate bending machine, and the plate-planing machine already described. Sometimes a manhole punching machine is worked by hydraulic pressure, and occasionally a beam bender, and some special forms of shears. Perhaps there is no process to which hydraulic power has been so much applied as to riveting. Nearly all new boilers, and all girders have their joints put together by the hydraulic riveter, and although the fixed riveter is not suited for shipyard operations, portable tools of the hydraulic order are largely used for riveting beams girders, and other parts separately before they are put into a vessel. It would be well if the portable riveter could be applied to the hull riveting. It has been done, but it is difficult of application there, as the frames interfere with its progress along the landings. If ships are ever built of plates alone, secured together by inside flanges, there will be free scope for the

full employment of the portable hydraulic riveter. But under existing arrangements there must always be a great many rivet holes which cannot be conveniently reached by this tool, whatever form it may assume.

Another question of importance in the economy of shipbuilding is how best to drive all the machinery,—whether by one large steam engine, by several small ones, or separate motors. Gas engines and petroleum engines have been used, in departments, for this purpose. These have their advocates, and the arrangement is convenient enough in works where the buildings are detached. But the worst of all systems seems to be that of operating all the tools of a shipyard by continuous lines of shafting, driven by a large steam engine. The arrangement is not so bad where an engine of short stroke is applied direct on to the main shaft; but what a lamentable mistake it is to set down a ponderous engine of long stroke in a big building, and on a massive foundation, and get up the speed on the shafting by driving a pinion by means of a huge cogged wheel. Whatever variations of speed the engine makes are multiplied four or five fold on the shafting and machinery.

Happily that system is becoming obsolete, but even yet it has its patrons and defenders. In some yards a preference is given to having each machine self-contained, *i. e.*, with its own motor attached to it. Others make a compromise, and find it most convenient to adopt more or less of both systems. Considerable diversity of opinion prevails among shipbuilders as to which is preferable for economy of working and convenience. The small engine, whether steam, gas, or electric, on each machine, seems, at first sight, to have many advantages, and there can be no doubt as to its convenience. Without taking into account the first cost of a large, cumbrous engine,—for that might be nearly balanced by the aggregate cost of the separate motors,—it is indisputable that belting, whether of leather or any other material as substitute, is very expensive



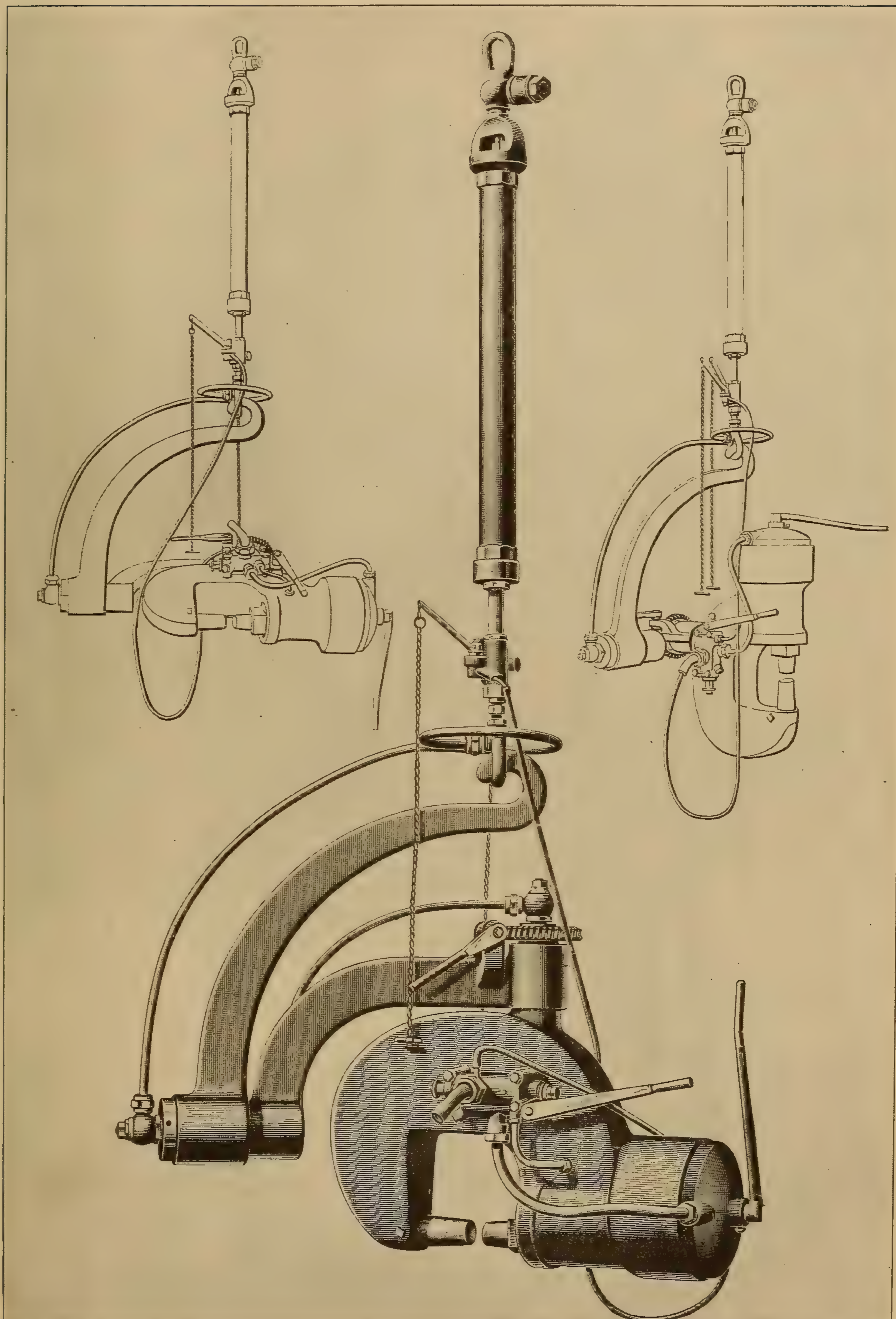
A HYDRAULIC ANGLE SHEAR, BUILT BY THE MORGAN ENGINEERING CO.

to maintain, and the machines driven by it almost always require to be under cover. These must be placed with their driving shafts parallel to the main shafting, or the belts will not remain on the pulleys. There is no such difficulty with a machine that has its own engine. It can be situated anywhere, away from the sheds or the shafting, at any convenient angle, and near to its work, or where it is most wanted. It simply requires, for a steam motor, to have a steam pipe led to it from a boiler. But there are users who have been unfortunate with their donkey engines. Their experience with them has not always been favourable, the reason being simply that their donkey engines have been got up on the "cheap and nasty" system, and in consequence have given no end of trouble. They have quickly shaken themselves to pieces, and been continually under repair. They have disgusted their owners by their frequent breakdowns, and the stoppage of the work in consequence.

It is not surprising if, after some irritating experience of that kind, many shipbuilders have condemned the use of separate motors, and have placed all their machines under their shafting, and driven them by belts and pulleys. But it is not the system that is at fault, it is the badly executed work. There is no reason why donkey engines should not be as durable, and work as steadily, as their owners' chronometers. It is simply a question of quality. If they are made of good material, with adjustable bearings and wearing parts, and fittings for efficient lubrication,—if they are made, in short, with as much care in design and workmanship as marine engines of the best class, these motors will not break down, nor become noisy, nor require frequent repairs. A few good toolmakers have awakened to this truth, and have seen the importance and credit of making their small engines of the best possible quality. In cases where really good engines have been supplied, they have given the utmost satisfaction, and have demonstrated very clearly the advantages of the separate motor.

It is seldom that all the machine-tools of a shipyard require to be at work at the same time. Some are idle for days; others are required only to perform a few revolutions at wide intervals. It seems absurd, then, to have all these machines connected to the main shafting, for whether they are doing work or not, their belts and loose pulleys, and other gear, must keep on running and wearing themselves out. If only one or two machines are required to be at work at overtime, the main engine must be kept going, and all the shafting, pulleys and belts of the establishment must be on the whirl, unless special arrangements are made for disengaging portions. This is not necessary where each machine has its own motor. One machine, or as many as may be wanted, can be started and stopped at any time, and the machines are only wearing themselves or needing lubrication while they are actually doing work. There is undoubtedly less tear and wear, and there can be little doubt that, in general, there is economy in the consumption of fuel for raising steam.

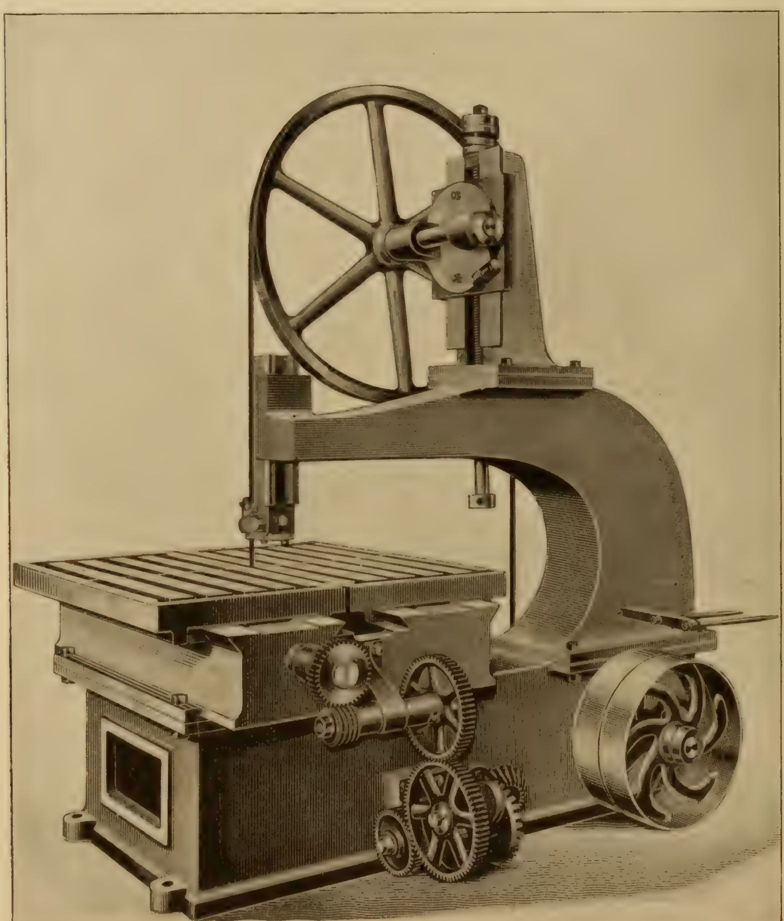
There is another advantage which may be alluded to. Uniformity of speed prevails where the machines are driven by a main shaft. But that is seldom desirable. There are times when it is an advantage to be able to run a machine faster or slower. A punching machine, for instance, is sometimes doing work that does not require the holes made with great precision of position. The machine is then made to go at a quick speed, and the attendant engine will run as fast as may be desired. But when great accuracy in the holes is important, the engine can be slowed and the holes punched with more deliberation. The speed desired may vary from 15 to 40 strokes of the punch per minute. A boy stationed at the stop-valve can regulate the speed to suit the workmen's requirements. Where machines are driven by belting, the speeds of all can hardly be satisfactory. An average speed is determined upon, and the sizes of pulleys are fixed accordingly, and this speed is, in many cases, too fast for some kinds



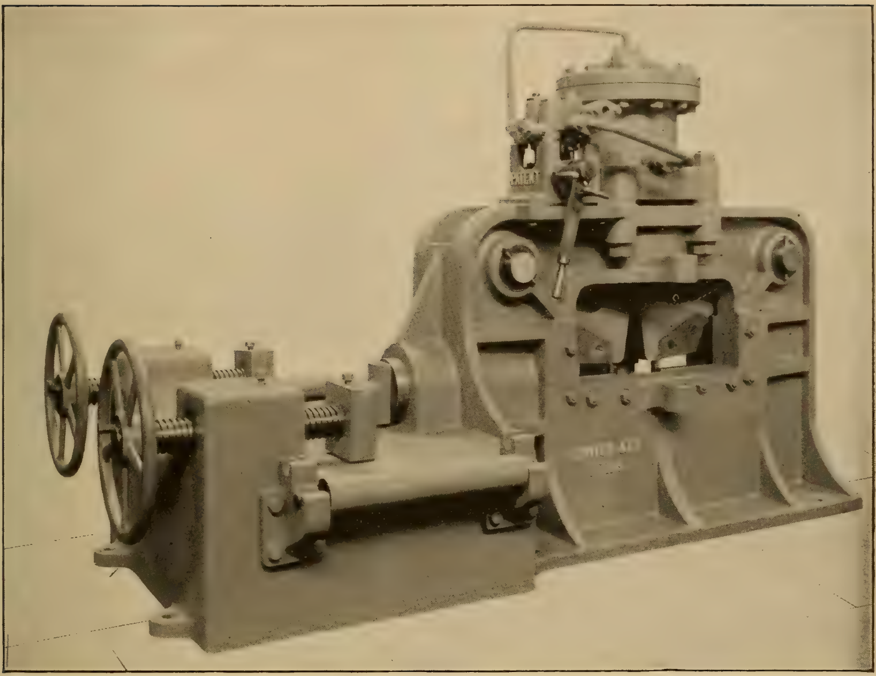
A DIRECT ACTING PORTABLE RIVETER AND HOIST, BUILT BY THE MORGAN ENGINEERING CO.

of work and too slow for others. There are many good reasons, then, for deciding in favour of the separate motor to each machine. There ought to be no governour on the motor. A young lad at the stop-valve is the best possible governour, and it becomes his duty to stop the machine when its work is over, and to keep it oiled and in good order. And now electricity is coming to the front in shipyard economy as a prime mover for driving machines. There is every reason to believe that a good electric motor, attached to each machine, instead of a donkey engine, would form a most valuable and economical appliance. It is, however, of too recent introduction in this rôle to be commented upon either favourably or otherwise. In another year or two there will be sufficient evidence of its behaviour and cost to enable shipbuilders and others interested to judge of its merits.

Some reference has been made to all the machine tools that are considered indispensable now in the iron or steel department of a modern shipbuiding yard. As regards their general quality and fitness to do the work required of them, it can only be said that in the yards of the Clyde, the Tyne and the



A BAND SAWING MACHINE FOR CUTTING IRON AND STEEL COLD, BUILT BY MESSRS. NOBLE &, LUND, FELLING, NEAR NEWCASTLE-ON-TYNE, ENGLAND.



HYDRAULIC DOUBLE ANGLE IRON CUTTING AND BEAM BENDING MACHINE, MADE BY MESSRS. SCRIVEN & CO., LEEDS, ENGLAND.

Mersey, in Germany, France and Sweden, and in not a few of the shipyards of America, are to be seen some of the finest machines of modern construction. Those of Scottish make are notable for substantiality and general fitness for their duties. They are free from any flimsy refinements, too often characteristic of tools of more southern origin ; just as the English make may be said to be superior to the Continental. But many of the shipyards of Germany, France and Sweden are supplied with tools of Scottish manufacture, and some of the large yards, such as the Vulcan Works, at Stettin, in Germany, may now be said to be quite as well furnished for the execution of large contracts as those of any country in the world.

Those who are familiar with the tools of different makers cannot but be cognizant of a certain individuality in the form and construction of each maker's machines. However much makers may borrow ideas from one another, their manufactures can be spotted at once by a certain peculiarity, not easily pointed out, but as distinctive, perhaps, as each maker's handwriting. The work of the poor designer, as well as the graceful proportions and impress of the good maker, can be recognized at a glance ; and between these extremes there are many features of personality with which every maker stamps his manufacture, identifying him almost as much as his name-plate.

A few machines have been omitted, for, though required in connection with a shipyard, they come more strictly under the definition of engineers' tools. Among these are the keel-bar drilling machine, which bores, or ought to bore, three or more holes simultaneously, and at varying pitch. Occasionally there are one or two lathes for repairs to the tools, and a scarfing or shaping machine. It may now be of interest to specify the number and principal functions of the tools required to well equip a modern shipyard of moderate size.

SIX-FOOT SLOTTING AND PLANING MACHINE, BUILT BY MESSRS. LOUDON BROS., JOHNSTONE, SCOTLAND.

I. One garboard strake or keel-plate bending machine, to take in plates up to 30 feet length and 1¼ inch thickness, worked by hydraulic pressure of 1500 pounds per square inch and capable of flanging steel plates of these dimensions cold.

II. One plate-bending machine, capable of curving and straightening plates 30 feet in length by 1¼ inch thickness; the top roller movable up or down by power gear, and the whole machine driven by a reversible steam engine having two inverted cylinders, 12 inches in diameter by 20-inch stroke.

III. One smaller plate-bending machine, say 20 feet in length, to curve steel plates 20 feet in length and 1 inch thick, same description as above.

IV. One plate-edge planing machine, the traverse of tool to be 30 feet length, but admitting plates of any length. Several small hydraulic rams, fixed in beam over table for securing the plates, screw of steel, 5½ inches in diameter, and 1¼ inch pitch, carried up by metal supports the full length, and driving saddle by a gun metal

half-nut, at least 18 inches in length. This machine should be driven by reversing belt pulleys from a shaft overhead.

V. One plate-edge planing machine, 20 feet traverse, same description otherwise as the preceding.

VI. Two lever punching machines, capable of punching, at both ends, steel plates 1½ inch thickness, with gaps 42 inches depth; to be driven by a steam engine attached having a cylinder 10 inches in diameter by 14 inch stroke. Crane jibs mounted at both ends, of 15 feet radius from centre of punch, and strong enough to carry plates weighing two tons.

VII. Two lever punching machines capable of punching at both ends steel plates 1½ inch thickness, with gaps 36 inches depth, to be driven by a steam engine attached, having cylinder 10 inches in diameter by 14 inches stroke; crane jibs mounted at both ends of 15 feet radius from centre of punch, and strong enough to carry plates weighing two tons.

VIII. One lever punching machine, same size and description as foregoing, but having, in addition, a side cutter with dies and shears suited for cutting or punching manholes, and for cutting out notches from the edges of stringer plates, the gap on side cutter to be at least 30 inches in depth. Three crane jibs of 15 feet radius should be fitted to this machine; to be driven by a steam engine attached, having a cylinder 10 inches in diameter by 14 inches stroke.

IX. Two lever double punching machines, to punch at both ends steel plates 1¼ inch thickness, with gaps 36 inches in depth; to be driven by a steam engine attached, having a cylinder 10 inches in diameter by 14 inches stroke; crane jibs at both ends, of 15 feet radius, to carry plates of 35 cwt.

X. One lever punching and shearing machine, to punch, at one end, steel plates 1¼ inch thickness, with gaps 36 inches depth; to shear at other end 1¼ inch steel plate with gap 28 inches depth, and to be provided with an angle iron cutter on one side to cut angle iron on the flat, and having independent stop motion, to admit and shear angles 6 inches by 6 inches by ¾ inches; steam engine attached, with cylinder 10 inches in diameter by 14 inches stroke.

XI. One lever punching and shearing machine, to punch, at one end, steel plates 1⅛ inch thickness, with gap 30 inches depth; and to shear same thickness with gap 24 inches depth; steam engine attached with a cylinder 8 inches in diameter by 12 inches stroke. Two cranes with radius of 15 feet, to carry up to 30 hundred weight.

XII. One beam-bending machine, to bend deck beams up to 14 inches breadth, and to punch horizontally at other end; steam engine attached with cylinder 7 inches in diameter by 12 inch stroke.

XIII. One plate straightening or flattening machine, having 7 steel rollers, to admit plates 6 feet wide and ¾ inch thickness; to be driven by a set of reversing belt pulleys.

XIV. One double angle iron shearing and horizontal punching machine, to cut angles up to 10 inches by 6 inches; and to punch 1¼ inch holes through bars 1¼ inches thickness.

XV. One mast rolling machine, to admit plates 12 feet in length; top roller of steel not exceeding 11 inches in diameter, and easily removable through one end of standard.

XVI. Four radial countersinking drills, having arms of 4 feet radius, and arranged to be driven by one shaft at 7 feet distance apart.

XVII. One triple drilling machine, suited for keel bars, the drills to be easily adjustable to any pitch.

XVIII. One portable steam hammer, on a jib of 12 feet radius, with telescopic steam pipe, adjustable by racking gear.

XIX. Two portable hydraulic riveters, with 3-foot gaps.

THE EVOLUTION OF THE FITTEST EDUCATION.

By Professor R. H. Thurston.

THE growth of our systems of education of youth, from the earliest days of Greece to the present time, affords some interesting suggestions to the student of processes of evolution, as illustrated in our social progress and in the gradual development of modern civilisation. That great ex-engineer, Herbert Spencer, has defined evolution as the transformation of the homogeneous into the heterogeneous, through a process of differentiation, or a succession of such processes.

Darwin has established the proposition, as relating to growth of living forms in nature, that all progress is the resultant of the action of two antagonistic principles—that which leads to the gradual change of species by a continual modification consequent upon the effort, on the part of the organism, to adapt itself more perfectly to its environment, and the constant action of that environment in the cutting off of individuals and of species which are not well adapted to their purpose, or to the preservation of the life of the race.

It is this struggle which results, finally, in the "survival of the fittest." It is also noted that there always exists a tendency to revert to the primary forms ; and, the influences producing modification of form being, at any time, relaxed, temporarily or permanently, the type resumes its earlier characteristics. All these conditions and all these effects are to be seen in the progress of education, the term being applied in the broad sense in which Paley used it.

A definition of the idea symbolised by the word education, in the broadest and truest sense, should, however, be made still more comprehensive than that offered by the great philosopher and divine who so greatly modified the course of evolution in morals during the last century. Education is not simply the sum of all those methods of preparation, practiced in our youth, for the sequel of our lives, as Paley has stated ; but it is, or should be, the whole system of preparation of youth for the life and work coming to the individual to help on the progress of the race by his influence with, and work for, his fellows. Perhaps it would be more correct to say that Paley's definition should be given a larger interpretation than is customarily assumed for it. The sequel of our lives should be defined as comprehending the duties of the individual to himself, to his family, to the nation, to the world, and to the race.

So interpreted, the definition of the philosopher seems to cover all those influences which mutually affect the citizen and his fellow men. It is in the light of this broadest definition of the subject of all education that we may study the progress of its development, of its evolution, as illustrated in the past and in the marvellously rapid changes which our generation has witnessed, and which are still going on with apparently accelerated velocity. Seeing most clearly the goal toward which all progress is directed, it becomes easier to trace and appreciate the movement taking place under the pressure of forces which are daily becoming more clearly defined and more definitely directed.

Could the future and its limitations be foreseen for each individual, it would be comparatively easy to determine what, under the circumstances, would be the best education for each ; this being impossible, it is evidently wisest to pursue

precisely the course which every good business-man pursues in all matters of importance in the daily conduct of his affairs,—to take a course dictated by the probabilities of the case, as revealed by his best lights, best judgment, and most instructive experience. If certainty cannot be had, proceed in a direction which is indicated by the strongest probability.

For each individual, and for every class of citizens, these probabilities may be usually quite safely determined and the course to be pursued in training it for the future can be, with a fair degree of safety, settled upon. For the man or the woman of wealth, and possessing talent in a defined direction, as in art or in music, it is evident that a gymnastic training that shall give the mind its best and most symmetrical development—that shall awaken every faculty and give it efficiency; that shall store the mind with such knowledge as will be most serviceable to a person of leisure and culture; that shall develop, train and render most effective the special talent which distinguishes the individual—is desirable, in addition to all the cultivation and instruction needed to enable the youth to successfully assume the responsibilities of citizenship and of family life.

For our average citizens, who must, in all probability, labour throughout the whole of life in this world, to secure the necessaries and comforts of life, it is equally evident that the first and most essential object of education and training should be—must be—the preparation of individuals, whether men or women, to assume the responsibilities and to perform the duties which are, by this exigency, forced upon them.

Beyond all this lies the requirement that the education of the youth shall fit him for rising above the position into which fate has forced him, and, still beyond this, the necessity of, if possible, preparing him to secure such of the intellectual pleasures, and to perform so much of the work of elevation of his fellows, as may be practicable.

For the simple-minded worker who has no talent, no ability to acquire knowledge through study, and but little power of learning through the senses, even—for that class which constitute so large a proportion of the working population of the world—it is equally evident that it would be absurd to attempt, as some one has expressed it, "to put a three-story education into a one-story brain."

For this class—a class which, in our public schools, is very apt to "differentiate" itself from its comrades of more intellectual mould—the best education is that which gives its members preparation for its special work in the hewing of wood and the drawing of water, a manual training and a physical education such as will best fit the student for his daily work in the field or the shop, and so much of intellectual development as is possible; beginning, as a matter of course, with the simplest elements of essential learning, and proceeding as far as the case permits in the awakening of a desire for knowledge and an appreciation of the advantages coming with its acquisition, even to the toiler whose compensation is a wage hardly sufficient to procure the most absolute necessaries of life.

It would seem from what has been just stated that education must be a very uncertain and ill-defined thing, that it must have one form for one person and quite another for another person; but a moment's consideration may, perhaps, show that education, public education, such as it is the duty of the commonwealth to offer to the children of its citizens, may be fairly well defined and classified, and adapted with a satisfactory degree of exactness to its purposes; even though it must be more or less well-adapted, ideally, to many different kinds of intellect and to many different conditions of life.

There are two grand classes of citizens, into which all our youth may be assigned, according to their characteristics and conditions of life:—those who are brilliant of intellect, or who by their talents and inclinations are fitted for the intellectual pursuits, for the professions in which the brain is the working member, mainly; and those in which the

constructive faculties, the hand working more or less in conjunction with the brain, are the working elements.

It is evident that, if the youth has developed a bent in either of these directions, his education will be the more efficient accordingly as it is directed the more skillfully and intelligently toward the end which the individual himself, thinkingly or intuitively, as the case may be, assumes for himself. But it happens that no fact in science is better established than that the nervous and muscular systems are so intimately related that the exercise of the one is essential to the welfare of the other. Especially is the health of the mental organism dependent upon that of the body. *

Whichever course is finally to be taken, therefore, the first step is one in which both the intellect and the body are trained together, the one being given the elements of an education which, in its first steps is the same for all ; the other being trained by the form of gymnastics which may as well be the use of the tools of the trades as any other—and probably better. If it were certain that the child would never use a tool, it might be as well, perhaps, to give him the gymnastics of his games only ; but kings may fall, and the child of any citizen is very sure to find many opportunities of practising the art which he may have partly learned when at school.

If it were certain that the child of the labourer were never to have opportunities to rise above the station to which he is born, it might not be advisable for the State to expend time and money in giving him other than an intellectually gymnastic training incidental to the process of teaching him the "three R's" ; but every citizen should be at least so far instructed that he may not find in his lack of primary education an obstacle to such upward progress as his talents, his ambition, and his enterprise enable him to attain.

A secondary education succeeds the primary, for those who are naturally fitted for profiting by it, and whose circumstances enable them to profit by such opportunities. This includes the latter part of the intellectual training, *per se*, and the special preparation of the student for professional work in professional schools, as for the law, the ministry, for the medical profession, or for that of the engineer or the worker at a trade, as such preparation is given in the technical schools.

Finally, the student goes out into the world to take up his life's work, or on into the technical school for a more complete training for that work ; and this last completes what is generally spoken of as his education, his "preparation in his youth for the sequel of his life."

Such is the method of education of youth to-day. It is easy to see how naturally it is divided into its several stages, and it is equally easy now to see what are the tendencies of changes now in progress, and the direction in which we may, in the immediate future, expect those changes to operate in the evolution of the "fittest education."

The work undertaken in the education of youth may evidently be thus divided into two principal departments. In the one, the student is taught those branches of knowledge which are intended to fit him for a later continuous growth in intellectual power, and in wisdom and knowledge ; the other is that which gives him the essential instruction and training in such technical work as may best prepare him for the pursuit or the profession in which it is expected that he will do his life's work. The one looks to the cultivation of the individual, the other to his preparation for taking his part in the work of the world.

It is obvious, on the most cursory study of the matter, that the primary studies of public schools are essential to both lines of study ; that the ethical and the æsthetic, the liberal and classi-

* Dr. Seguin, senior, once sent me an account of a case of partial paralysis of the left side, accompanied by the loss of mental power, in a child of six years of age, suddenly occurring in consequence of convulsions brought on by some digestive irregularity, and cured by simply cultivating the tactual power of the partially disabled hand and arm. The mind was strengthened as the hand and arm became stronger and both approached their original, normal power together.

cal, education must be given before the technical, if the latter is to be added to the former ; and that the professional school should be post-graduate to the academic department.

It is evident that what I have sometimes called the "ideal education," that in which the pupil is given, first this general preparation and gymnastic training, then a liberal education—in a broader sense than classical, of course—and, finally, a thorough professional education and training, whether for law, for medicine, for the pulpit, for the engineer's office, or for the work-bench, or the mill, is the natural birth-right of every citizen in the ideal commonwealth.

It is a singular fact that the ideal state is best illustrated by the monarchical nations of Europe. The freedom of the United States, for example, has, curiously enough, been one of the difficulties which has impeded the progress of the "evolution of the fittest education," while the arbitrary systems of government of Germany and of France have, as it has happened, best promoted its development, the centralised and personal will, once having been directed into this work, having caused a systematic, symmetrical, and prompt introduction of all the elements essential to steady, rapid, and healthful progress. Germany and France are generations ahead of Great Britain and the United States, mainly, perhaps, because the free nation has been governed by the larger body of citizens, a body of which the representatives have not yet thought out the scheme of the best education to its full extent.

This "ideal" education is what I conceive to be the "fittest education" and the process of its evolution is now taking such form that its growth can be readily traced and it can be seen that the full development has not yet been reached, although it is now rapidly assuming that perfected form which will best fit the educated citizen to his environment. We have seen each element of the ideal education gradually evolved during the past history of the race, and we are now witnessing the opening of the period of co-ordination of the several parts to form the perfect whole.

Primary education has taken shape in the schools of Europe and of America, and has reached maximum extension in the common-school system of the United States. That liberal education, which is considered by all wise and learned men to be essential to the formation of the truly educated and cultivated citizen, has been moulded by the hands of the best and greatest educators of all civilised countries into a form which has become fairly defined, and is familiar to all the cultivated people of all nations. Professional or technical education has been given form in France and Germany, and has begun to take shape in the United States, and to assume its proper relations, part with part, and of the whole to the other departments of education. As time goes on, we see it more and more frequently becoming complementary to the primary and the liberal educations, taking its proper place as the crowning member, the cap-stone, of a magnificent edifice.

As the country and the people gain in wealth and brain-power, it seems not at all too much to hope, that we shall see a larger and larger proportion of the great body of citizens securing the advanced forms of education, and supplementing their primary studies by the one or the other of the two higher lines of work, and more and more frequently able to secure, even, both the liberal and the technical.

Already, in the technical schools, we are finding considerable numbers ot young men coming from the colleges and universities into our professional courses, and are seeing the advantages of this more complete training in their maturer thought, more earnest spirit, and more thorough appreciation of the opportunities and privileges offered them. The advantage possessed by such a completely educated man over the merely technically educated, or the merely liberally educated, man is best seen when the struggle for success in the great competitions of life begins.

With equal natural ability and equal adaptation to the chosen profession, the "ideally educated" youth moves ahead promptly, and easily keeps the lead.

If choice must necessarily be made between the liberal and the technical, neither time nor money being available for the prosecution of so long a course of study as includes both, the young man going into any profession will usually, and wisely, choose a professional course. This is the customary method to-day. But the more complete education is none the less desirable, and the fact is becoming recognised more and more generally, every day.

Thus "the homogeneous," as Spencer would call it, is becoming transformed into the "heterogeneous." In the earliest days of formal education, all pupils were taught the same studies, and these studies were simply the accumulated wisdom of the individual instructor. Written systems of knowledge were simply, as a rule, speculative; all students were taught a certain formulation of so-called science and speculative philosophy, without much regard to its application "in the sequel of their lives." There was no system of real education, no undisputed and indisputable science. Technical education, as a system, was undreamed of. As time passed, the old monastic, classical education took form, gradually became developed into the modern "liberal education," and, as such, remains, to-day, a distinct and well-defined course of instruction and gymnastic training.

Finally, the professional schools were brought into existence, beginning with well-organised schools of law, and less well-organised schools of medical empiricism, and gradually came the formation of all the modern classes of technical school. Now we are seeing these several systems of education brought into proper relations, and becoming parts of one greater whole—that ideal education which includes the primary, the secondary, the liberal, and the professional schools.

It is this gradual progression which has so well illustrated the conversion of the homogeneous into the heterogeneous. Every such evolution results in the production of a heterogeneous body in which all the parts are definitely related to all other parts and with them combine to form a system, a whole.

In the process of this evolution we also see illustrated the action of those forces which control the resultant effect: the action of the environment in producing and directing growth; the restraining influence of inertia and that conservatism which insure healthy and moderate development. The demand of the race for wisdom and knowledge, which aspiration was born of its needs in the struggle for life and for all that man desires in this world, gave rise to formal education; the needs arising in the course of its progress, the environment of individuals and of nations, compelled growth and improvement; the circumstances affecting the wealthier and more intelligent classes produced the development of a liberal education; while the technical educations came in similarly in compliance with the necessities and the intelligent demands of those who propose entering the gradually increasing number of professions having a basis in the applied sciences, whether natural or other.

The tendency to revert to older forms is seen to be present in the conservatism of those, educators as well as other citizens, who would condemn and obstruct all innovations, and would go back to the simple gymnastic education of the middle ages as the best and only satisfactory preparation of the youth for the sequel of his life.

But, in education, as in all external nature, such a restraining force is healthful and desirable, and will always prove advantageous. It will never prevent progress, but will always insure that the advancement is healthful, and that the result shall finally be the evolution of the fittest form of education, the fittest for the time; but the fittest for the time will not be the fittest for aftertime, and we may be sure that this process of evolution of the best education will never cease. As the world moves, so will its evolutions continue.

THE SHAFT GOVERNOUR.

By E. T. Adams.

TWENTY years of hard service have shown the shaft governour to be the weak spot in the modern high-speed engine,—the part that calls most urgently for adjustment and most often for repairs, and, withal, it is the vital part, the part that has developed the high-speed engine. Valves and valve connections are designed to humour its whims, flywheels are made heavy or light at its bidding, and its performance is as safe and accurate an index of the engineering status of the builder as can possibly be found.

The shaft governour is not necessarily an element of weakness, and if in many instances it has proved to be the chief source of annoyance and expense, it is mainly because simplicity and durability were not sufficiently considered in its design. In the earlier designs less attention was given to these points. Close regulation was the quality chiefly sought after, and with a success that has won for these governours first place among the devices for regulating the speed of a steam engine.

But ability to give close regulation is not the only essential in a first-class governour; in fact, it is beginning to be realised that it is the one easiest of attainment. Strength to resist the growing infirmities of age is also an essential, and one far harder to secure. Any builder of high-grade automatic engines can guarantee extremely close regulation; but few can furnish a governour whose useful life will bear any reasonable proportion to that of the other working parts of the engine.

It has taken time, years of service and rough usage to point out the weaknesses that the earlier designers did not foresee. Only within a very recent period have the demands of the electrical industries taken definite form and come to be fully and clearly understood. In fact, we may safely say that it is only now, with the mistakes of the past and the demands of the present, both set clearly before us that we are able with certainty to designate the qualities that distinguish the governour that is not a weak spot in a modern high-speed engine.

What these qualities are we may best determine by a study of a few late designs of recognised merit. Of the governours taken for analysis, some have stood the test of several years' trial for all classes of service, and some are yet undergoing private tests preparatory to placing them before a critical public; but all are taken as representative of the best practice of to-day and as showing best the lines along which all designers of shaft governours are now working.

Before taking up these governours in detail it may be well to consider briefly a few of the problems presented to the designer of a shaft governour and the forces with which he has to deal. The most obvious work of the governour is to shift the centre of the eccentric across the shaft, thus regulating the point of cut-off to suit the demand for power made upon the engine. This implies, in the governour, power not only for the work of governing, but power as well to withstand the thrust of a heavy valve, moving at a high rate of speed.

Difficult and trying as this seems to be, the problem of securing power presents less difficulty than the necessity of obtaining both sensitiveness and sta-

bility,—an instant response to any demand on the engine, without undue fluctuation before steadying down to the required speed,—and to secure this with a form that is simple and durable, fitted to perform its work quietly, continuously, and with absolute certainty.

The necessity for durability points to a strong, simple construction, few parts, few joints, the latter of ample area and thoroughly and continuously lubricated. For sensitiveness and stability the requirements are the same. True, the usually accepted theory calls for a centrifugal weight opposed by a spring adjusted to isochronism, the tendency of this unstable combination to violent "racing" being controlled by a dash pot; but this theory neglects the friction in the joints and attempts to concentrate it in the dash pot where it will serve some useful purpose. Practice shows that better governing has not been obtained than is secured by nearly isochronous adjustment and the elimination as nearly as possible of all friction, including the dash pot. Friction, of course, is greatly lessened by adopting a simple construction; in fact, simplicity is the ounce of prevention for almost every ill to which the shaft governour is heir.

The problem of lubrication in an open wheel with a rim velocity of not far from a mile a minute is not easily solved. The joints of a governour, subjected as they are to heavy pressure, with but slight motion, are of a class always most difficult to manage, but doubly so here, where oil must not be thrown either on belt or armature.

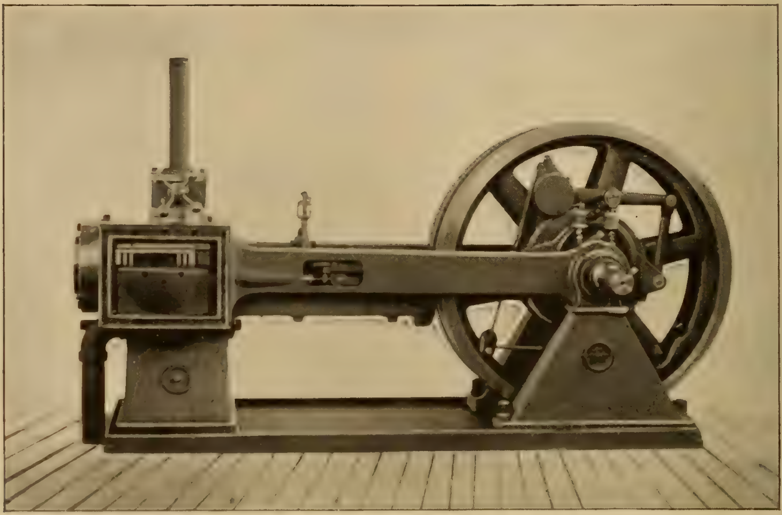


FIG. I. THE STRAIGHT LINE ENGINE GOVERNOUR AND VALVE.

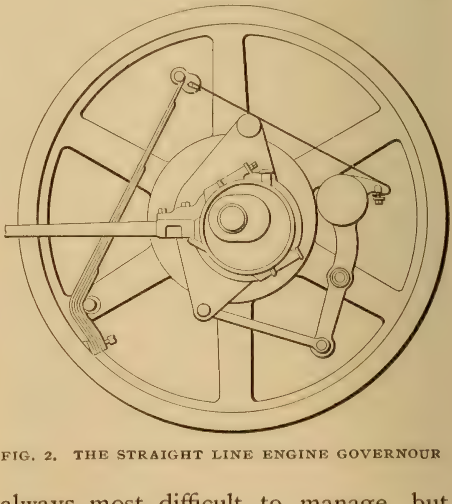


FIG. 2. THE STRAIGHT LINE ENGINE GOVERNOUR

Knife-edge bearings, where possible, and graphite bushings are largely used, but evidently the true remedy is to reduce the number of bearings. This also greatly lessens the chance for lost motion and the consequent rattling. Every joint, we must remember, is constantly searched by the thrust of a heavy valve, which amounts in effect to not far from half a million heavy blows each day. In fact, when we consider the dangers and difficulties that are introduced by a complicated form, the surprising thing seems, not that the governour is often a weak spot, but, rather, that it will operate successfully and quietly as long as it does.

In addition to the thrust of the valve we have the force of the spring, centrifugal force, and the force of gravity. These, with the effect of friction and inertia, make all the forces acting in a shaft governour. A study of the governours described in this article will show substantial agreement in utilising these forces, excepting that due to inertia. Upon this difference has grown up a classification, daily growing more common, into inertia and centrifugal governours, which is decidedly misleading.

Considering only those governours in which the point of cut-off is changed by moving the eccentric across the shaft, there are certainly two distinct classes, the one suitable for light, easily driven valves; the second, designed to stand the increased duty imposed by the heavier partially balanced valves used by some of the foremost builders of engines of this class. But all are centrifugal governours and all are inertia governours in this sense, that the designers have taken into account and made use of the forces due to motion and to change of motion. Opinions may differ as to how these forces shall be utilised, but these differences hardly seem a reasonable basis on which to make a classification. In fact, it hardly seems that a classification is necessary, unless possibly the exigencies of advertising call for one.

In the early days of the automatic engine Prof. John E. Sweet, then connected with the mechanical engineering department of Cornell University, designed one of the simplest shaft governours that has ever been produced. There are but four pieces, including the spring, and the whole is unique among shaft governours in that time has developed no weakness, and the governour, as built to-day, is the same in every respect as the governour of the first Straight Line engine which is still giving most excellent service at the works of the Straight Line Engine Company at Syracuse, N. Y., U. S. A.

Of the governours now on the market but two—the Buckeye and the

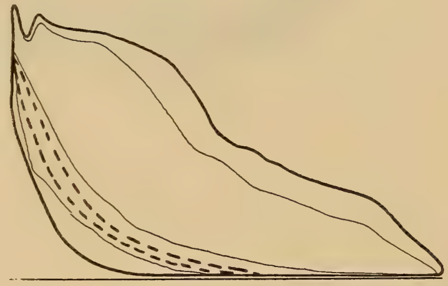


FIG. 3. A STRAIGHT LINE ENGINE DIAGRAM.

Payne—were produced prior to the Sweet governour. A great many different forms, some of them exceedingly complicated, appeared later, but no governour on the market, of either ancient or modern design, gives closer regulation or promise of longer life. This governour is used by the Straight Line Engine Company, the Ames Engine, the Cooper Engine, and, with an immaterial change, by a firm of engine builders in the Western part of the United States.

It was clearly the aim of the designer to secure a form that was simple and strong, and to reduce to a minimum those unbalanced forces that could not be wholly eliminated. Hence, we find practically perfect gravity balance in all positions, the tangential effort of inertia reduced as nearly as possible to zero, and friction and the thrust of the eccentric rod lessened in every way possible. The bearings are few in number, and provision is made for oil-

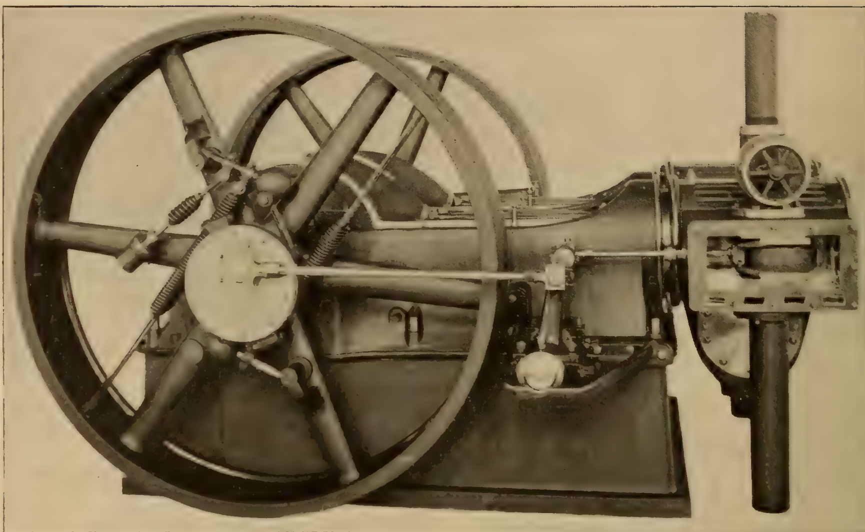


FIG. 4. THE BALL GOVERNOUR.

ing while the engine is running. The valve is perfectly balanced, and both valve and connections are made as light as possible. The weight used is heavy, and is placed well out from the centre, making a powerful governour, and a very slight change in speed gives ample power to shift the light, balanced valve.

Figs. 1 and 2 represent the governour and valve of this design. The card shown in Fig. 3 was taken from a 9″x12″ Straight Line engine. Running light, the engine made 288 revolutions. With a 40 H. P. brake load the speed was 284, a total variation of less than 1½ per cent. or less than ¾ of 1 per cent. variation from the mean speed of the engine. The indicator pencil was held against the paper while the engine made five turns; then the load was removed instantly and the pencil held while the engine made five turns more. The card shows that the adjustment for this load was made in the fourth part of one second or less, and that there was practically no vibration after the change. The weights simply moved from one position to another and came easily to rest. There was no dash pot to check the movement of the weights.

In the diagram the full lines show the card for full load; the dotted line is the friction card, and the light full lines show the path of the governour during the change of position and while coming to rest.

There are disadvantages attending the use of any form of balanced valve. It is difficult to prevent leakage with a piston valve, and the adjustable feature of the flat balanced valves is, in some respects, objectionable. Hence, we find many of the foremost builders of automatic engines using a partially balanced valve that will remain tight, and that does not require adjustment.

The advantages secured by a valve of the type used by Ball or Payne are not secured free of cost. A valve of this class is heavier and requires more power to drive it than is necessary with the best designs of balanced valve; consequently its power to disturb the action of the governour is greatly increased. This has led designers of governours, intended to drive valves of this type, to interpose some device, commonly called "a locking device," that shall make the governour strong to resist the action of forces along the line of the eccentric rod. This usually introduces considerable complication.

The principle involved in nearly all such devices is the same, but it is illus-

trated in its simplest form in the Ball governour. In this governour, shown in Fig. 4, the valve is driven by a crank pin. This pin is fixed in a plate bolted to an eccentric strap, the pin, plate and strap being, in effect, one piece, which is free to turn on an eccentric, bolted to the hub of the governour wheel.

It is evident that any force that can be applied in the line of the eccentric rod will be almost wholly expended in producing pressure between the eccentric strap and the eccentric, and, except for the additional friction that this produces, the force required to drive the valve has practically no effect tending to disturb the action of the governour. Any motion of the weights turns the strap and plate about the eccentric, carrying the pin that actuates the valve across the shaft in a path shown very clearly in Fig. 5. Besides giving practically constant lead from quarter cut-off out to full stroke, the path chosen has the further practical advantage that it makes possible the use of an eccentric much smaller than would otherwise be required.

The governour weights are of moderate size, placed at a considerable distance from the centre of rotation. A small change in speed makes a considerable change in centrifugal force, and the moment of this force, tending to shift the eccentric, is large. This makes a very powerful governour. Friction and inertia forces, due to change of speed, are eliminated as far as possible, the inertia of the eccentric strap and plate being opposed during the greater part of the stroke by that of all the other moving parts of the governour.

The parts subjected to wear are large and strong, and seem as well adapted to withstand wear and rough usage as any part of the engine. As a whole, the governour is durable, powerful and simple—qualities that should guarantee good regulation every day during long years of service.

Fig. 6 shows the governour side of a McEwen engine, with the steam chest cover and balance plate removed. The openings shown above and below the valve connect with passages in the balance plate, through which steam is admitted to the cylinder past the outside edge of the valve. This governour is the first of the so-called "inertia governours," and, as the cut shows, its latest form is very simple. There is but one weight, one spring and one bearing, which, being provided with roller bearings, makes lubrication unnecessary.

Identical in principle with the McEwen governour is the Rites single-weight governour, which was designed independently and simultaneously by Mr. F. M. Rites and Prof. R. C. Carpenter, and which is now being thoroughly tested, under the supervision of Mr. Rites, by a prominent firm of high-speed engine builders. The Rites governour has several new features, of which the most striking is the ex-

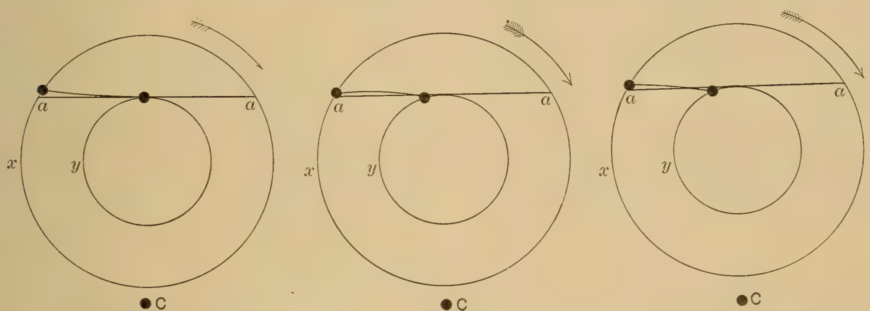


FIG. 5.

ceedingly neat combination of a dash pot and receptacle for the spring. In both these governours much has been sacrificed for simplicity. With but a single weight it is impossible to secure a gravity balance or to balance the inertia forces developed with each change in speed of the engine. In each the weight is so pivoted that the effort of its inertia tends to make the governour more sensitive, acting with centrifugal force to reduce the travel of the eccentric when the speed of the engine is too high, or, if more work is required, acting with the governour springs to so shift the eccentric as to make the point of cut-off come later in the stroke.

This plan of utilising any unbalanced inertia force in a governour is not new; in fact, it is characteristic of the best practice of to-day, but it is a distinctive feature of these governours that the weights are of such form and so pivoted that for any change in the speed of the engine, the moment of the inertia force is as great as possible. This makes an exceedingly sensitive governour, but one that will develop a tendency toward violent fluctuations unless most carefully designed. If a well-made dash pot is used, it is safe to guarantee that the average number of revolutions per minute will not vary over one per cent. for any change of load on the engine. In a recent test of a Rites governour it was found possible to so adjust it that the speed, when the engine was loaded, was 20 revolutions faster than when the engine was running light. In this there was no dash pot and no "racing." An adjustment of this sort is not, of course, practically desirable, but it shows more clearly than any other illustration the high degree of stability that it has been possible to secure without decrease of sensitiveness or use of a dash pot.

The friction of these governours should be very small. There is but one joint, and in the McEwen governour this has roller bearings, their use being one of the novel features of this design. A feature of the Rites governour—the receptacle for the spring—is one that will be appreciated in situations where the flying fragments of a broken governour spring might cause considerable damage. A noticeable feature of all these governours, but one especially prominent in the Rites and McEwen

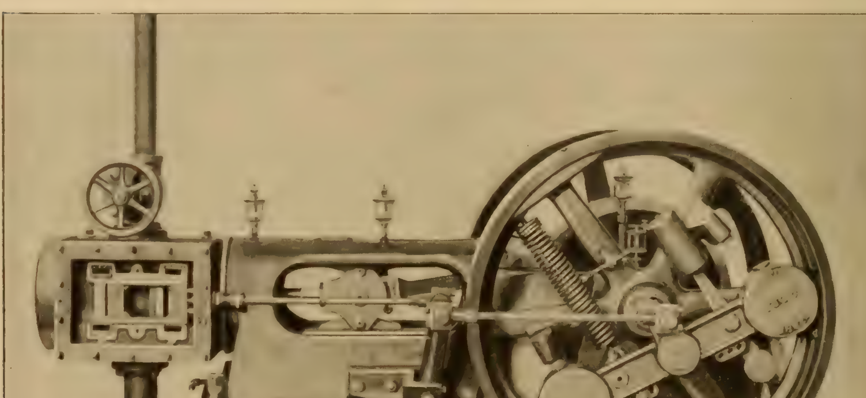


FIG. 6. THE MCEWEN GOVERNOUR.

types, is the short radial motion of the centre of gravity of the weights,—a feature whose good influence is too often overlooked. The inertia of the heavy weight used in both governours easily absorbs the thrust of a balanced valve, giving stability, and the strong, simple construction is a guarantee of long years of service.

Considering these governours as typical of the best practice of to-day, then durability is the chief consideration in modern design, and in every case it is secured by adopting a strong, simple construction, with few joints, and those made strong, with ample surface to withstand the duty that falls upon them.

Good regulation is the next consideration, and while the governours mentioned differ in minor details, they agree that ample power is the chief essential to secure it. All have heavy centrifugal weights, placed well out from the centre and opposed by strong springs. Under these conditions a very slight change in speed furnishes power to shift the eccentric any degree necessary to provide for the change in load of the engine.

Friction, the worst enemy of good regulation, is in each case reduced as much as possible. It is, of course, greatly lessened by the choice of a simple form with few bearings. It is further lessened by knife-edge bearings where possible, and when the ordinary form of bearing is used, provision is made for its continuous lubrication, preferably by the use of some form of graphite bushing. The use of oil in the swiftly revolving wheel is decidedly objectionable.

Gravity balance for the parts of the governour is, in general, considered to be an essential. The inertia of the weights, their property of resistance to change of any kind, is utilised to give stability, and in many forms it is the only safeguard necessary to prevent disturbance by the forces acting along the eccentric rod.

The inertia forces, due to change in speed of the engine, are, in the Carpenter and McEwen governours, made as great as possible by making the weight heavy and pivoting it near the centre of the wheel. The more general construction is to so place the weights that this force shall have practically no component tending to cause motion.

As is proved by the cards which have been shown, centrifugal force alone furnishes ample power to give instantaneous response to any demand made on the engine. Over the inertia force, once it is called into action, we have no control. It must be expended in work, probably acting *with* centrifugal force when the change in load is considerable and made suddenly, and acting *against* centrifugal force when the change is slight. The test of the Rites governour just alluded to shows, however, that it is possible to secure with this type most excellent results, and its extreme simplicity is also a most desirable feature. In fact, the results obtained with these governours leave but little to be desired, as any one of those described will easily give regulation within one per cent.

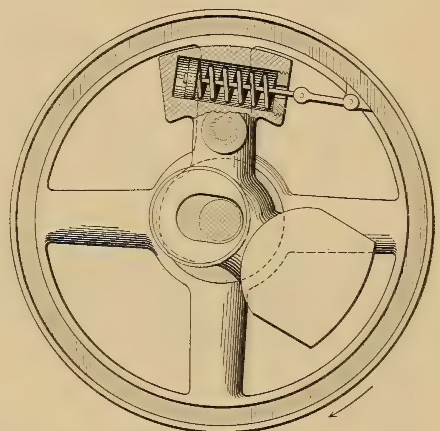


FIG. 7. THE RITES SINGLE-WEIGHT GOVERNOUR.

The path of the eccentric across the shaft possesses considerable interest. The tendency seems to be to give the valve negative lead for the early points of cut-off and positive lead for the later points. This gives a longer expansion period, less compression and less change

in the compression curve, with change in the point of cut-off,—a refinement introduced by Prof. Sweet, but also appreciated by other builders, as is shown by reference to Fig. 5.

With the governour made strong and durable, the simple automatic engine is brought to a degree of perfection not excelled by any other type, and it would seem that engineering skill has done about all that can be done, and that the magnitude of its future field of usefulness has become mainly a question of finance to be wrought out by the financier and the consulting engineer.

T E MILLING DISTRICT AT NIAGARA FALLS.

NEW POWER DEVELOPMENTS AT NIAGARA FALLS.

By Orrin E. Dunlap.

THERE seems to be no end to the power facilities at Niagara Falls. The locality offers many advantages for the development of cheap power, and since man fully realised all this, capital has recognised it as a safe field for investment. The oldest power project at the Falls is the hydraulic canal,—an open waterway which diverts a portion of the water of the upper Niagara river from its natural channel and conducts it to a basin situated about 300 feet back from the high bank of the lower river. From this basin it is conducted by flumes to the penstocks of the turbines of the mills now operated there.

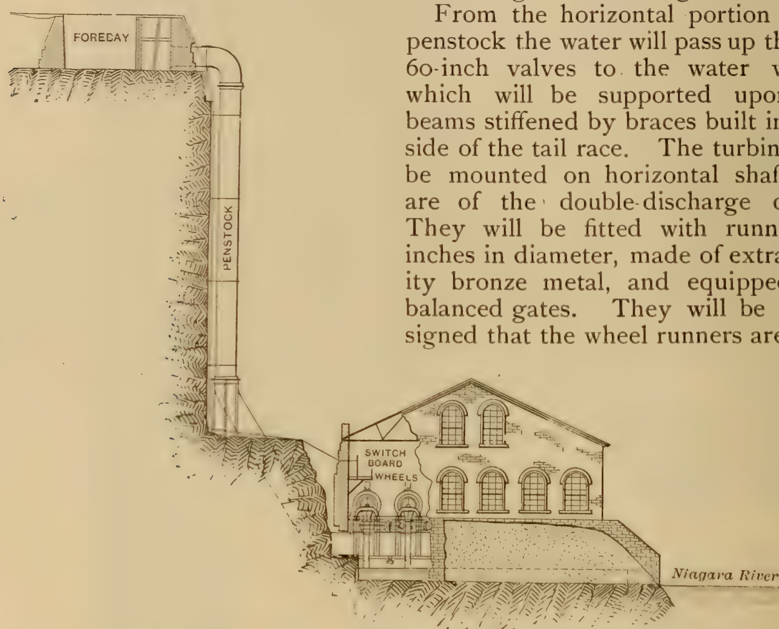
For the past few years the owners of this canal, the Niagara Falls Hydraulic Power and Manufacturing Company, have been expending large amounts of money in widening their possession in order to obtain a greater water supply and thus increase their power facilities. The work of enlarging the canal is now practically completed, and the company have prepared plans and commenced work on what is destined to be a power house and plant of considerable magnitude.

This new power house is to be located on the sloping bank at the edge of the water in the river below the Falls. To prepare for the construction of the building it was necessary to clear the site of the broken rock and bowlders which had laid undisturbed for centuries, In some places the mass was from 75 to 100 feet deep and represented the droppings from the high cliff for ages of time. The removal of this debris was, in itself, no small task, but the service of a hydraulic "Giant" or "Monitor" was brought into use for the first time in that locality, if not in the eastern part of the United States. This machine is very extensively used in the gold mining districts in the West for excavating by a powerful stream of water. When the debris was all removed, a substantial stratum of sandstone was found, and on this the new power house is being erected.

The building will be of stone, 60 feet long and 100 feet wide, but ultimately, as demand for power makes it necessary, the length of the building will be extended. For this plant water will be carried in an open canal, from the basin before referred to, to a forebay 30 feet wide and 22 feet deep, which is now in process of construction between the

PREPARING FOR FOUNDATIONS BY MEANS OF HYDRAULIC MONITORS.

edge of the high bank and the basin. From this forebay, penstocks of flange steel, eight feet in diameter, will conduct the water down the slope, a distance of 210 feet, to the power house at the edge of the water in the lower river. These penstocks will lead from the forebay vertically about 135 feet to the top of the bank slope, thence down this slope to the side of the power station next to the bank, thus making the total length of the eight-foot pipe about 240 feet.



CROSS SECTION OF THE NEW POWER HOUSE OF THE NIAGARA FALLS HYDRAULIC POWER AND MFG. CO.

Pipes 10 feet in diameter will run horizontally into the building and be suspended over the tail race leading from the station. The thickness of the steel in these pipes will be 15-16th inches. All horizontal joints will be butt-strapped and held with three rows of rivets on each side. The cross seams will all be double-riveted. Strong work in all parts is made necessary by the fact that the total pressure on the end of the pipe will exceed a million pounds.

At the start, four turbines of the horizontal type, having a capacity of about 7000 H. P., will be located on the first floor of the station. Each turbine will be fed by a separate penstock and work under a head of 210 feet, which is said to be the highest head under which water has ever been used in the quantity proposed in this new Niagara plant. It is for this reason, to counteract the effect of the enormous pressure, that every detail of the penstocks and water wheels have been designed with the greatest care.

From the horizontal portion of the penstock the water will pass up through 60-inch valves to the water wheels, which will be supported upon iron beams stiffened by braces built into the side of the tail race. The turbines will be mounted on horizontal shafts and are of the double-discharge design. They will be fitted with runners 74 inches in diameter, made of extra quality bronze metal, and equipped with balanced gates. They will be so designed that the wheel runners are absolutely balanced by the equal discharge of water on each side, thus avoiding end-thrust on the shafts. They will be in cases 11 feet in diameter, made of the best heavy-plate steel and will be double-riveted.

The feeder pipe connections to these large cases will be on the bottoms of the same, and riveted directly to the five-foot hydraulic cylinder valves, all of which valves will be connected to the main feeder pipe, which will be 10 feet in diameter, and occupy space under the turbines between the foundation walls. These shafts will be of the very best quality hammered wrought iron,

THE POWER HOUSE IN COURSE OF CONSTRUCTION.

carried in adjustable ring-oiling bearings and mounted on heavy cast-iron bridge-trees.

The four initial wheels for this station will be built by James Leffel & Co., of Springfield, O. Three of them are guaranteed to develop 1700 H. P. under a head of 205 feet, which is the minimum head estimated as obtainable, and to run at a speed of 250 revolutions per minute. As the ordinary head used will be from 210 to 215 feet, the power from these wheels, it is expected, will be from 1800 to 2800 H.P. each. These three wheels will be connected to six electrical generators, two to each wheel, and the power will be used by the Pittsburg Reduction Company, manufacturers of aluminium, in a new factory to be built on the top of the high bank, to which point the electric energy will be transmitted. The fourth wheel will be connected to two 560-kilowatt generators and will make 300 revolutions a minute. It will furnish a 500-volt current for street railway or general power purposes.

The work is in charge of W. C. Johnson, chief engineer of the Niagara Falls Hydraulic Power & Mfg. Co.

LORD ARMSTRONG, C. B.

AMONG the illustrious men who have rendered the nineteenth century remarkable for the wonderful advance that has taken place in scientific knowledge and mechanical invention, and who have, as it were, opened out a new era in our civilisation, Lord Armstrong, the subject of this sketch, takes a prominent place.

William George, Baron Armstrong was born at Newcastle-on-Tyne on November 26, 1810, and is the son of William Armstrong, a merchant of that city. His father was a man of considerable attainments, being, among other things, an advanced mathematician, and took a prominent part in local affairs. He was for many years chairman of the River Tyne Committee, a body now known as the Tyne Commission, and in 1850 he filled the office of mayor of Newcastle. He was one of the founders of the Literary and Philosophical Society of Newcastle, and of the Newcastle Natural History Society. Mrs. Armstrong, his mother, was a lady of high literary culture, greatly beloved by all who knew her. Lord Armstrong was one of two children ; his sister, who was a few years older than himself, married Mr. William Henry Watson, a barrister, for some time member for Kinsdale, who afterwards was raised to the bench, and became Sir William Henry Watson, Baron of the Exchequer.

From earliest childhood the subject of our sketch took great delight in mechanical toys, in pulling them to pieces and in forming new mechanical combinations. Nothing ot especial note is there to remark about his schooldays. He was sent to school first at Whickham, in Northumberland, and thence to the grammar school at Bishop Auckland to complete his scholastic education. Two incidents may be mentioned which occurred during his boyhood and which might have prematurely closed his career. When about five years old, he was taken to a windmill near his father's house, and while his nurse was talking to the miller, he wandered off and clambered up among the machinery connected with the arms of the mill. Had the wind begun to blow he must have been killed, but, fortunately, he was discovered in time, and rescued.

On another occasion, while at Wickham School, he and other boys were gathering nuts in the precipitous ravine, which is crossed by Tanfield Arch, when the ground on which he was standing at the edge of the cliff gave way, and he was precipitated from a height of some fifty feet ; he must have been dashed to pieces on the rocks beneath had not a strong hazel bush arrested his fall, and thrown him into a deep pool of water, enabling him to escape with only a wetting, and a few scratches and bruises.

At Bishop Auckland lived Mr. William Ramshaw, whose daughter Margaret he married in 1834. She was a lady of great force of character and generosity, and for over fifty years of married life her chief source of pride was her husband's success. She died in 1893.

When he left school, an opening was found for him in the office of Mr. Armorer Donkin, a prominent North Country solicitor, and an intimate friend of his father. There he completed his legal education, if we except a year that he spent in London, reading

CRAGSIDE, LORD ARMSTRONG'S HOME.

law in the chambers of Baron Watson, then a special pleader. He eventually became junior partner in the firm which thenceforth was styled Donkin, Stable, and Armstrong, and for about fifteen years practised assiduously as a solicitor. During the whole of this time, however, he employed his leisure in folowing his natural bent for science.

At Cramlington Colliery near Newcastle a curious phenomenon was noticed. A jet of steam escaping from an accidental aperture, gave rise to small electric sparks when it came in contact with the engine man. Armstrong studied the cause of the phenomenon, and found that it was due to friction. He made apertures of various forms, and of various materials, and eventually produced his hydro-electric machine which, for a considerable time, maintained its supremacy as the most powerful machine for the production of high-tension electricity.

The invention attracted great attention both in England and on the Continent, and at once brought his name into fame in the scientific world, leading to his being elected a fellow of the Royal Society in 1843 at the early age of 33. His proposer on that occasion was no less a man than the great Faraday. His principal hobby outside the region of science was fishing, of which art he was a renowned expert.

One day, in 1836, when wandering

in the vale of the Dent, in Yorkshire, his attention was attracted by a water wheel, fed by a stream that descended from a great height, and he noticed that only about twenty out of several hundred feet of descent were utilised. He felt convinced that if the stream could be conveyed from its summit in a pipe, and caused to act by pressure at the base, the whole, instead of only a part, would be utilised as a motive power. The result of this, after years spent in patient endeavour, was the invention of the hydraulic crane, which greatly added to his fame as an inventor.

In 1844 the Newcastle and Gateshead Water Company was formed. His firm were solicitors to the company, and he was enabled to point out how his system of hydraulics might be beneficially employed in connection with their undertaking. They adopted his ideas. A hydraulic crane was erected on the Quayside in Newcastle, the pressure from the company's water pipes being employed as the motive power. It proved a great success. Engineers came from all parts to see it. Cranes were widely ordered, and the system has since been gradually introduced into all the great ports of the world. The principle has since been extended, and is utilised for the working of lock gates, moveable bridges, and a great variety of other purposes.

The invention of the hydraulic crane proved to be the turning point in Armstrong's career. He gave up the profession of law, and, with the help of his partner, Mr. Donkin, and a few other friends who joined with him, the Elswick works were started for the manufacture of hydraulic machinery. As town water works could not be depended upon for supplying pressure, he was soon led to the invention of the accumulator system which removed all difficulty as to the distribution and efficacy of hydraulic power, independently of town water works. This gave a great impulse to the primary invention, and has resulted in the spread of water pressure machinery all over the world.

The year 1854 opened out a new era for the Elswick Works. From reading an account of the battle of Inkerman, which described how the victory was aided by two 18-pounder guns, dragged with great difficulty into action, Armstrong was led to turn his thoughts to the science of gunnery and came to the conclusion that weight could be diminished, and both range and accuracy increased by changing the material of the gun, and adopting the system of rifling the bore. This resulted in the invention of the Armstrong gun with which his name is popularly associated.

His first gun was a 3-pounder, which, with its carriage and ammunition, and all necessary accessories, cost two years of constant effort and a great outlay of money to bring to maturity. It was referred to the Ordnance Select Committee of that day, but did not receive from them much consideration. They said it was too small to judge by, and criticised it as a "pop gun." Armstrong then bored out his gun to the calibre of a 5-pounder, which was accepted for trial, and its success led to the ordering of an 18-pounder gun and to the appointment of a special committee to investigate the whole subject of rifled ordnance, and to report upon the best system.

A long course of experiments followed, in which the Armstrong gun was placed in competition with many others, and was eventually recommended by the committee as the best. It was accordingly adopted by the British government, and the inventor made a present of his invention to the Nation. He was thereupon knighted, made a C. B., and appointed Engineer of Rifled Ordnance, with a salary of £2000 a year. This post he retained from 1859 to 1863 when he rejoined the Elswick firm. From that time till 1882 he directed the affairs of the firm, which constantly increased in its business relations with foreign powers until it had made guns for almost every civilised nation.

In 1882 the Elswick company entered into a new course of existence, and, amalgamating with Messrs. Mitchell and Swan, an eminent Tyneside firm of

THE DRAWING ROOM AT CRAGSIDE.

shipbuilders, was converted into a limited company under the title of Messrs. Sir W. G. Armstrong, Mitchell and Co., with Sir William as chairman of the company. The subsequent history of the company is one of unrivalled success. Their works are among the largest in the world, employing about 15,000 men. They have built some of the largest battle ships and some of the fastest cruisers afloat, and have established works at Pozzuoli, in Italy, which form the ordnance arsenal of that country. From this time Lord Armstrong gradually withdrew from the internal management of the works, confining his attention to the external direction of the affairs of the company, living almost entirely at his beautiful home of Cragside, near Rothbury, in the valley of the Coquet, about 30 miles from Newcastle.

In 1863 he was president of the British Association when it met at Newcastle, and his presidential address on the probable duration of English coal, in which he put 200 years as the probable duration of the best seams in the country, created a profound sensation at the time, and led to the appointment of a royal commission on the subject. He was a member of the commission, which sat for nearly two years, and the duty of drawing up the voluminous report was deputed to a committee, of which he was chairman. The closing words of his presidential address have had a remarkable exemplification since they were uttered. He said:—"We may expect, therefore, to increase our speed as we struggle forward; but however high we climb in pursuit of knowledge, we shall still see heights above us, and the more we extend our view, the more conscious we shall be of the immensity that lies beyond."

Besides having been president of the British Association, he was president of the Institution of Civil Engineers in 1882, and has been three times president of the Institution of Mechanical Engineers. He became president of the Literary and Philosophical Society of Newcastle in succession to Robert

Stephenson, and has remained president ever since. On the centenary celebration of this society two years ago, at the commencement of a lecture that he gave on electricity, he was able to make the interesting statement that his father had assisted in founding the society one hundred years before, and, that fifty years before, he, himself, had lectured before the society.

In 1872 he went to Egypt, in company with Sir John Fowler, to report to the Khedive on certain engineering schemes, and embodied his experiences in four interesting lectures to the members of the Literary and Philosophical Society, which have since been published.

In 1886, on great pressure being brought to bear, he was induced, at the sacrifice of his well-earned leisure, to come forward, at the age of 76, as the Unionist candidate for Newcastle ; but the tide in the North having set in in favour of Gladstonian principles, coupled with a labour dispute then going on, he was defeated. The following year, on the occasion of Her Majesty's jubilee, he was raised to the peerage as Baron Armstrong of Cragside, an honour which gave the greatest satisfaction to the people in the North of England and to all who knew how thoroughly it was merited.

Distinctions of all sorts have been showered on him. He has been granted the honorary degree of LL. D. from Cambridge University, that of D. C. L. from Oxford, and Master of Engineers from Dublin. He has received the Albert medal of the Society of Arts, and the Bessemer medal. He is also a Knight Commander of the Danish Order of the Dannebrog, the oldest order of chivalry in Europe, and of the Order of Francis Joseph of Austria, of Charles III. of Spain, and the Rose of Brazil. He is Grand Officer of S. S. Maurice

IN CRAGSIDE PARK.

BAMBURGH CASTLE.

and Lazarus of Italy, and only last year received a high grade of the Order of the Rising Sun of Japan.

In Newcastle Lord Armstrong's widespread philanthropy and generosity have caused his name to be enrolled among the greatest benefactors of that city. He employed his genius for landscape gardening in beautifying Jesmond Dene near the town with such great success that people travel long distances to see it. He then presented this beautiful pleasance to his native city together with about 54 acres of land near Newcastle which has been converted into a park, now known as the Armstrong Park. He gave £10,000 towards the building of the new Natural History Museum, one of the finest provincial museums in the United Kingdom, and there is no institution in Newcastle or th eneighbourhood, worthy of support, whether religious, educational, or philanthropic, that has not benefited largely by his assistance.

Cragside, his seat near Rothbury, founded by him 33 years ago, is a standing witness to his taste and genius. Built on what was once a barren hillside, he has so planned and laid out and planted the surrounding grounds that their fame has spread far and wide, and attracts annually numbers of pleasure seekers to Rothbury, while the maintenance and extension of these works enables him to find employment for a considerable portion of the male population of Rothbury. Everywhere in the grounds are found the impress of the master mind.

Cragside was the first private house in England lighted by electricity, which is there generated by water power. There Lord Armstrong has entertained crowned heads, princes and ambassadors, not to mention some of the most distinguished scientists of the day, the most recent royal visitor being H. H. the Shahzada. At Cragside he lives a life of extreme simplicity, devoting himself, notwithstanding the weight of years, to the management of his estates and farms, for he takes a great interest in all agricultural pursuits, being the owner of a well-known herd of Shorthorns. Never idle, he fills up his time with experiments in electricity, on which he has recently read papers before the Royal Society, at London, and in the performance of those duties that usually fall to the lot of a country gentleman, and he has filled for years, to the general satisfaction of all, the chairmanship of the Rothbury Petty Sessions.

In 1873 he filled the office of High Sheriff of Northumberland. Only last year he became the purchaser of the historic castle of Bamburgh from Lord Crewe's Trustees, to which he hopes to restore some of its pristine glory, and the work and restoration has been placed in competent hands and is now being vigorously carried on. A portion of the castle is to be devoted to the uses of a Convalescent Home, to which he has already granted an endowment of £20,000.

Such, then, is the record, briefly told, of the life of one who, by his energy, genius, and philanthropy, has not only built up for himself a lasting and wide-spread reputation, but has also conferred great and untold benefits on his fellow-men.

THE EXPERT ENGINEER.

By H. de B. Parsons.

THOUGH the name or title of "expert" is often applied to the engineer, it is objectionable; not only because it is often misapplied, but because the word has become so general in its application that it no longer conveys a definite meaning. The term is usually applied to a person well versed in some particular line of work and able to give a fully up-to-date opinion thereon.

On account of the great extension of knowledge that is now taking place in various diverging lines, it is evident that no one man can be an expert in more than a very few branches. Every engineer of standing considers himself an expert in at least one branch of his work. Strictly speaking, the expert engineer should be a person of sound judgment, fully able, as well as willing, to consider with unbiased mind the merits or demerits of any plan or proposed improvement that may be brought before him. If the man be biased, or opinionated, or a "crank," he cannot truly be called an expert. Every man is, to a more or less limited extent, narrow in his views on certain subjects, and it often happens that some of the brightest and most successful men are those most strongly opinionated; in fact, a man without strong likes and dislikes is generally considered weak.

Any man may be an expert in his sphere of work, no matter whether it be a profession, a business, or a trade, and due consideration should be given to his opinion, provided, of course, that he has the requisite personal capabilities. A man's ideas must necessarily be somewhat influenced by his surroundings. Therefore, when the opinion of an expert is given, the value of the man must be considered as well as the value of his experience, and this personal value is a factor often difficult to appraise.

It is said that a good designer should not be one whose business it is to operate the machine of his creation. Yet, there are many who strongly oppose this idea and claim that the contrary is an essential requirement. Certainly this latter proposition may be true, but in a general sense is it always so? The answer would seem to be "No;" because, if one has devoted his whole time to the operation of a certain machine, he cannot have become familiar with all the different kinds of devices in use. His practical experience must be limited to certain ones, and when he finds a device that suits him, he adopts it, and continues to use it. If such be the case, he becomes an expert in the use of that particular device, and loses his value as an expert in that "class" of devices. This is seen every day, when engine runners continually ask for a special grade of pack-

ing or a special make of valve, their selection depending in many instances on geographical position.

On the other hand, the designer is not so apt to be limited in his ideas, and his freedom of design is less likely to be narrowed or biased. If he use a device that is not satisfactory, he soon hears of it, and he naturally studies the failure, and takes care in the future to correct the difficulty.

The same is true of all classes of work. No one admits that the janitor is as capable of designing a building as the architect, but he is unquestionably more familiar with its details of operation. He is valuable to the architect as an expert on convenience of arrangement of details, just as the practical operator is to the designer, and, to obtain the best results, both should be consulted. This co-operation is necessary in all branches. A successful man of business may have made his reputation as an organizer, but the same man, if placed in charge of the details of a business, might utterly fail.

Time has so changed our surroundings, the practical man, self-educated by hard knocks in the world, is no longer able to successfully cope with the problems of the day. In consequence, the vocation of the consulting engineer has become firmly recognized as a true profession, and in this line of work there is a steadily increasing demand for the young, well-educated man.

As it is impossible to faithfully serve two masters at the same time, an engineer should choose either the position of consulting engineer or contractor. There are many, however, who try to act as both, and call themselves "Engineers and Contractors." This title, while strictly correct, is often misleading and often misused. A contractor should not enter the field of the consulting engineer, nor should the consulting engineer undertake contract work. Both may be expert in their own spheres, but each is apt to be biased, and thus unfitted to serve the client to best advantage. A contractor would naturally favour plans that he had been accustomed to, or plans that he could easily and cheaply handle without making additions to his working plant.

On the other hand, the more varied experience of the consulting engineer would render him less fettered by ordinary conditions, and thus make him better able to give the best solution of the problem in hand. He, of course, should not undertake to do work with which he is not familiar; and the client should select one who has made a special study of the class of work to be accomplished. If the engineer make designs for work with which he is not familiar, he is sure to fail; and it always takes many successes to balance one failure. It may therefore be assumed that an engineer of good reputation may safely be employed as an expert.

At times the client is placed upon the horns of a dilemma, and the situation is often very complex. If he call for bids on contractors' plans, the prices, as well as the plans, will be found to differ so widely as to make a selection of the best for the least expense a very difficult matter. If he have an expert prepare plans and specifications, then all bids are directly comparable; and practice has proved, time and time again, that on account of the more direct competition between the bidders, the reduced bids under this method will more than offset the fee to the consulting engineer.

The contractor, however, tells the client that if he be allowed to prepare the plans, he will guarantee the work, but will not do so if the plans are prepared by another. But practically, what does this guarantee amount to in case of a slight failure? It always ends in the client being obliged to accept the work, defect and all. If the defect be great, the whole, of course, can be condemned.

In order to make the guarantee of value, it is necessary to establish a premium as well as a penalty, and then the cost of the contract increases in proportion as the penalty is enforced. It is perfectly possible for a client to protect his expert's plans by a proper clause in the contract, and by making

the contractor sign the designs. Then, if there be any fault in the plans or calculations, the bidder will find them and refuse to sign for the guarantee.

The whole question seems to hang on the selection of a proper consulting engineer as the expert for the client. It has, therefore, become necessary for the consulting engineer to sub-divide his work, and specialists are found in all branches of engineering. Of course, there are engineers of different degrees of standing, and the client should select his professional adviser with some care. When retained, the engineer should work for the best interests of his client, but should bear in mind also that the contractor has some rights which are to be respected. In the end, it is a wise policy to let the contract only on figures which will insure for the contractor a fair working profit ; otherwise, he will take no interest in the work, make use of inferior materials, or rely on extras to make up the deficit. This is always a costly method for the client, and can be largely, if not wholly, avoided by the employment of a reliable consulting engineer at the beginning of the work. The engineer should draw such specifications as will fully cover the details, and so superintend the construction that costly extras may be avoided.

A certain steel building was to be erected, and the owner asked the contractor for plans and estimates, believing that he could thus save the engineer's fee. The plans were afterwards sent to a consulting engineer, some question having arisen regarding strength, and were returned with the statement that there was considerable room for improvement. The engineer was asked to prepare plans, which plans were afterward taken by the same contractor for $18,000 (£3,600) less than his first bid of $140,000 (£28,000) on his own plans. The new arrangement was larger and more convenient in every particular, the saving being effected by careful study to reduce weight in parts under light stress and to put material where it was most needed.

Many instances could be given with similar results, the saving always being far in excess of the engineer's fees. There is nothing astonishing in this, because the contractor has little interest except in securing the work, while the engineer gives his time and thought to the subject, because success means to him increased reputation and therefore a larger clientage.

Consulting engineers have often made mistakes by accepting the supervision of work that has already been commenced, without clearly defining their position. Such a condition is dangerous, because, on the completion of the work, all mistakes are likely to be charged to the engineer, whether the errors are of his making or not.

Work of any magnitude should always be designed complete before any part is commenced; for, if not, it is difficult to arrange the last to properly connect with the first. Clients are very apt to have their work done in this latter manner, thinking that it will hasten the completion, as well as cheapen the cost. This the engineer should do his best to prevent, for it is a method almost sure to lead to extras and troubles, and to bring the expert into disrepute.

There is another class of work which has greatly discredited the expert, and that the furnishing of so-called "expert testimony" in court. There are many men of unscrupulous nature, ever eager to oblige a client, who do not hesitate to testify to anything they are told. The fault lies not only with the witness, but also with the lawyer who is willing to engage such men to further his chances of securing a successful issue of the trial, irrespective of the merits of the case. Technicalities are often taken advantage of, both to rule out a true expert and to permit a non-expert to give expert testimony. If all the absurdities could be gathered, the reading would be very ludicrous.

The expert should have no direct interest in the termination of the case, and should simply limit his testimony to facts as they exist, or to his opinion of the conditions as found. He should study the case in advance, and should consent to testify only when he believes

his client has the rights of the case on his side. When the expert's reputation has been made in this particular, it will be found that his testimony will carry great weight with the court, outside of the simple meaning of his replies.

Some time ago there was a case on trial, for which an expert was retained. He declined to testify on the lines as laid down by the lawyer, and pointed out that the testimony asked for would not stand the cross-examination; A new line of testimony was thereupon mapped out, and the case was easily won. Here, the client had retained a non-scientific lawyer, who did not fully realize the conditions at issue, and the instance serves to show the advantage to be derived by the client in securing an expert who was capable of properly posting the attorney on the scientific principles involved, and who, by his experience in court, as an expert, could successfully guide the lawyer in that part of the trial.

In all cases the expert should be so paid as to be able to devote sufficient time to listen to the whole case, and thus be prepared to answer to the cross-examination, as well as to suggest questions for the examination of the opposition experts. In a case recently tried, the parties did not take this precaution, and lost their case, because the opposition qualified an expert who testified to certain dimensions regarding the width of railway platforms, directly contrary to what had been published in a book of which he was the author. It was on the fact of his having written this work that he qualified as an expert witness, but, of course, neither the lawyer, the court, nor the jury could be supposed to know what he had written; and as the case was a one-day trial, there was not sufficient time to investigate. Had the plaintiffs in the suit made their expert sit in court, the fact would have become known, since their expert was well posted as to the contents of this special work, he having supplied most of the information himself.

Nothing is more reprehensible than the practice in use by many lawyers to simply retain an expert, and then neglect to properly study the case with him in advance. The attorney should never omit to do this, and should always discuss with the expert every point that is likely to be brought out on the trial. In default of this precaution, a careful expert should always refuse to testify, as he is apt to be absolutely at the mercy of an astute lawyer on the cross-examination; and, if the case be an important one, he is likely to lose, unjustly, his reputation as a good witness. Let the expert always base his testimony on facts and not change from suit to suit. A case was once thrown out of court, because the experts testified directly opposite to what they had testified in a similar case some years before. The expert for the opposition knew this, and brought it to the attention of his lawyers.

Some lawyers often resort to sharp practices to reduce the standing of an expert, and these practices at times have great effect on a jury. It is commonly, but erroneously, supposed that every scientific expert knows everything, and questions entirely irrelevant and immaterial are asked, such as information on some of the tables of weights and measures, which, perhaps, the witness has not used since he was a boy at school. No distinction is drawn between the actually useful and the occasionally applied information.

It is often pitiable, however, to listen to the replies of a so-called expert to the questions of a "know-all" lawyer. An actual case occurred when the lawyer asked how to find the volume of a pyramid, and the witness promptly replied: "Multiply one side of the base by the average height." The lawyer taking this answer as correct, asked how the volume could be found if the sides of the base were irregular, to which the answer came that "the sides would have to be calculated from the area." The witness was qualified on this information as an expert, and his testimony recorded as such.

It is just these cases which have tended to place the expert in an unjust light before the public, and it is not uncommon now to hear men say that they

would not believe any expert unless they personally knew what he said to be true. But, after all, the right kind of expert testimony should carry great weight, be respected, and taken as the most advanced knowledge of the day.

Current Topics.

An old argument with many boiler-makers has been "the more tubes, the more heating surface," and it is not so long ago that by far the larger numbers of boilers built were laid out on this line. Gradually, however, the conviction gained ground that there might be a maximum number of tubes for any given boiler, beyond which it might be undesirable to go, for economical reasons, and it is now becoming generally recognised that the old plan of literally packing the lower half of an ordinary tubular boiler with tubes is altogether wrong. A larger tube-diameter—three inches—is coming into wider use, and the tubes themselves are no longer carried so close to the bottom and sides of the shell as was formerly the case. One immediately apparent result is that there is less chance with this disposition of clogging up of the water-spaces with mud and scale deposits, and less difficulty in cleaning out what accumulations may form. One other point to which attention has been directed several times by *The Locomotive*, an admirable little publication for steam-users, issued by the Hartford Steam Boiler Inspection and Insurance Company, is that if, say, the two lower rows of tubes in a boiler whose tubes extend down close to the shell are plugged up, the efficiency is not impaired.

Bearing on this, *The Locomotive* says: "By studying the progress of the heated gases as they leave the furnace, it will be seen that they pass over the bridge wall, lick the bottom of the boiler its entire length, and then turn upward at the rear end and enter the tubes. The levity of these heated gases carries them mainly to the upper rows of tubes, and only a small portion of them enters the lower tubes. To demonstrate this in a way that will be understood by all, a clean piece of soft white pine was placed at the front end of a boiler, nearly in contact with the ends of the centre (vertical) row of tubes, and was left in that position for several days. When again examined, it was found that the end of the stick in contact with the upper tube was burned

to a coal, so that it barely held together; at the tube next below it was little less charred, and the effects of the heat decreased more and more toward the bottom. Against the two lower tubes the wood was only a little discoloured, showing that the upper tubes were most effective, while the very lowest were of little account.''

ANOTHER fault with the ''close'' arrangement of tubes cited by *The Locomotive*, is that, besides the trouble from deposit of sediment, there is no body of solid water for the heat to act upon as it leaves the furnace. Great difficulty has been experienced with this arrangement of tubes, particularly when used with bad water. It gives a greater area of tube surface, but a considerable portion of the surface so gained is useless, and worse than useless, from the fact that the water space is unduly taken up by the superfluous tubes. In an approved arrangement of tubes the lower row is well up from the bottom of the boiler, leaving a good solid body of water for the heat from the furnace to act upon. The tubes are kept well away from the shell of the boiler on the sides, no tube being nearer than three inches to the shell, and a space of double width is provided for between the centre (vertical) rows of tubes. Good circulation is obtained, and the boiler is much more easily cleaned and maintained at its maximum efficiency.

SPEAKING recently of the vibration of buildings, due to running machinery in them, brought to mind an experience recorded several years ago by Mr. C. H. Ott, in a short paper before the Engineers' Club of Philadelphia. Mr. Ott told of the rocking of a four-story building in a city block, which, at certain hours of the day, was very perceptible. It was noticed in the rolling of water in vessels and swaying of gas fixtures, and could be plainly felt, so much, in fact, that several of the employees of the establishment on the top floor of the building were affected by a sensation similar to seasickness. On the rear of the building a chimney had become so loosened and shaken by the pulsations that it was necessary to have it torn down and rebuilt. The matter became so serious as to threaten the stability of the structure, and active measures were taken to ascertain the cause, and, if possible, prevent the pulsations.

IT was found that no motion or vibrations of a similar character and tending to affect the building in question were noticeable in any of the buildings in the remainder of the block, the occupants of which were not even aware of any trouble. The buildings in the row had all apparently been erected in a good, workmanlike manner, with suitable foundations, and unless there were unseen defects in the work, the theory first advanced, that the undulation was caused by the passage of heavy traffic in the adjacent streets, could not be entertained. It was noted that the motion was felt only during certain hours of the day, viz., between 8 A.M. and 6 P.M., and this led to the conclusion that it was caused by some heavy piece of machinery operated in some adjacent building, but investigation failed to find it. After much inquiry and search, it was discovered that in the rear fourth floor of a building nearly 400 feet away there was a small steam engine, used for grinding spices and coffees. No suspicion was at first attached to this piece of machinery as a cause of the trouble, from the fact of its being an engine for light duty, small in size, and its being so far away from the building affected, and from the fact also that its motion could barely be felt in the building in which it was located. Experiments were instituted, by starting and stopping the engine at stated intervals, a proceeding which immediately proved it to be the cause of the trouble. As a matter of convenience, the engine was then supported by pillars from the cellar floor, but without causing the desired effect. Finally, it was lowered

to the cellar, a proceeding which gave entirely satisfactory results.

A VERY neat form of guard for water-gauge glasses has been devised by Mr. Webb, of the London & Northwestern Railroad. Water-gauge glasses, as every engineer knows, sometimes break under pressure, and when they do, the consequences are not always harmless to those in the immediate neighbourhood. In fact, in many instances, serious bodily injury has resulted from the flying fragments of glass. To prevent these from doing any damage, Mr. Webb proposes to encircle the glass tube with a helical wire spring. This forms a good support to the glass, and when fracture does take place, holds the pieces together. One other advantage claimed for the arrangement is that the spring keeps the glass at a more uniform temperature, and, therefore, tends to lessen what chance there may be of destructive strains from unequal heating. In the event of fracture, the glass can be easily removed by slightly compressing the wire spring, which can then be taken from the recesses at the ends into which it fits.

TO WHAT extent a labour-saving device can be made to effect an economy has been very strikingly demonstrated in the case of one of the large electric illuminating companies which recently concluded to fit up each one of its arc light poles with a clock-switching device, designed to automatically throw into and out of circuit each of the lights at certain hours of the evening and morning, and thus to supplant the services of the men hitherto employed to make the rounds of the poles and do the same thing by hand. The company had at the time 600 arc lights in use for street illumination. The lights were 400 feet apart, and the city contract specified that they all had to be turned on not later than fifteen minutes beyond a certain hour of the evening, and might be again turned off not earlier than fifteen minutes before a certain other hour in the morning. Experience had shown that a man could walk about 4000 feet in a fifteen-minute interval, and turn on or off the ten lights within that distance, so that, for the whole 600 lights, the services of sixty men were required, which could not be secured for less than $4 per week per man, entailing, thus, the expenditure of $240 per week, or $12,480 per year. The clock-switching devices, which did the same work cost $5.50 apiece, making a total, for the 600 poles, of only $3300, which investment, of course, will not be a yearly recurring one. What the saving effected by the automatic switches will be may be left to the reader's own calculation. The whole affords a lesson in central station economics in which station superintendents ought to find something decidedly interesting.

THERE is a story of several years' standing, to the effect that at one time a locomotive on one of the lines running across the German-Russian frontier was used most successfully as a carrier of contraband goods, and that the fraud, so long practiced, was discovered only while overhauling the engine in the repair shops. The exact circumstances cannot now be called to mind, though the essential fact of such illegal use having been made of a legitimate piece of engineering work is brought back to memory by a recently published item which chronicles a somewhat similar bit of deception. The Belgian customs authorities, it appears, knew for a long time that large quantities of jewelry were smuggled over the French border, but how it was done puzzled them. In the luggage van of the express which runs between Paris and Brussels is a case, which holds the storage batteries when the train is electrically lighted. A key of the case is held by the conductor of the express, a foreman porter and an excise official of the border station, but none of these ever appear to use it. The other day, as the train ran into Quèvy,

the border town, a customs inspector took it into his head, more through officiousness than suspicion, to open the chest. To his amazement, it was filled to the lid with watches, chains, rings, bracelets, and all kinds of dutiable jewelry. It was found that the foreman porter at Quèvy had, for a long period, been carrying on a contraband traffic for a well-known Paris jeweler, who, it is said, has had to disgorge heavily, both in jewelry and hard cash, in consequence of the disclosure of his frauds.

In view of what was tried years ago in the way of burning pulverised coal under boilers, with the one object of getting the best possible combustion, it is worth noting that Messrs. Bryan Donkin & Co., of London, are now experimenting in the same line, using what is known as the Wegener system of powdered coal firing. Whether this will give any better results than those of earlier date remains to be proven, though in several respects the new method possesses apparently commendable features. The London *Engineer*, in speaking of it, says that small sacks of the powdered coal, weighing about half a hundredweight, are put into a conical hopper. The coal gradually falls out of the sacks, as required, into the hopper, and then on to a sieve, about 5½ inches in diameter, with small openings in it. The powdered coal would not go through this with certainty without continual tapping, and this is done in the following way :—Immediately beneath the hopper, and level with the boiler-house floor, is an air-pipe about twenty inches in diameter, through which nearly all the air for combustion enters. As it enters, it is made to pass through the blades of an air-wheel, or turbine, and this passage of the air causes the latter to revolve like a smoke-jack. On the axis of this air-wheel there is a little knocker which taps the sieve about 150 or 250 times a minute, causing the powdered coal to descend vertically through the sieve, meeting the air for combustion as it ascends vertically.

The powdered coal and air for proper combustion in this way get mixed pretty thoroughly and pass on into the boiler-flue, each particle of coal being surrounded by air. There is no grate and there are no fire-doors, and the stoking simply consists of putting a sack of powdered coal from time to time into the top of the hopper and seeing that the right amount of air is going in for combustion. If there is not sufficient air for proper combustion entering through the main opening, as would be shown by a little smoke, there are two smaller pipes through which additional air can be admitted. The only object of the air-wheel revolving, from fifty to eighty revolutions per minute, is to shake the sieve and cause the powdered fuel to go into the furnace in the quantity desired. When more steam and coal are desired, a greater knock is given to the sieve and more powdered coal is burnt; when less is required, less shake is given. A screw adjustment for knocking is provided, to regulate the amount of coal entering. The fireman really has nothing to do but to put the sacks of coal into the hopper and to regulate the amount of air for proper combustion. Analyses of the waste gases are said to have shown the combustion to be excellent.

In the museum of the Royal United Service Institution, now appropriately placed at the Banqueting House in Whitehall, there is a capital collection of models, which, besides the great models of the battles of Trafalgar and Waterloo, includes a few remarkably good examples of ancient and modern ships of war. These ship models have recently been increased by the addition of H. M. S. "Powerful," which is claimed to be the most perfect example of modelling in existence, and is said to have cost £800. The cost of the models naturally suggests an inquiry as to that of the full-sized ship. On this matter a good deal of information was given recently by Professor Elgar. In the English dockyards the average cost of a

first-class battleship, such as the "Royal Sovereign," is £843,590, while the vessels of a similar class built in private yards average out at £882,792 each. The first-class sheath protected cruisers, like the "Royal Arthur," are built in the dockyards for £397,026, while the private yards produce them for £374,181. The first-class unsheathed protected cruisers, like the "Edgar" and the "Hawke," cost in the dockyards £402,231, while those of a similar class turned out from private yards cost £360,565. The second-class sheathed cruisers, like the "Brilliant," cost in the dockyards £214,740, while the private yards build them for an average of £186,631. The second-class unsheathed cruisers, like the "Apollo," cost £189,772 in the dockyards, as against £174,936 when built privately; and the third-class cruisers, like the "Pallas," cost £157,222, as against £123,050. Taking the British fleet through, Professor Elgar is of opinion that government-built ships should be about ten per cent. cheaper than those from the outside builders, although it is evident from the instances given that this state of affairs does not at present exist. Enormous as the cost of these vessels may seem, it should be borne in mind that, owing to the increased use of machinery and the decreased cost of material, it is now possible to build ships of war, as well as ships of commerce, for half the money that it would have required thirty or forty years ago.

WATCHMEN are of little benefit in a shop or factory at night, and even the most perfect watch service will not compel a man to stay awake when nature demands sleep. This is the opinion of Mr. C. F. Simonson, the general inspector of the Hartford Fire Insurance Company. In an address, recently, before the officers and special agents of that company, in which he spoke of the manner in which night watchmen perform their duties, he proposed the following plan, instead of the one usually followed:—Select two men, capable and fit to be watchmen, sweepers or helpers; let one begin his shop-work at noon. When the factory closes at night, he takes a round, until satisfied that everything is all right and in proper shape, then eats his supper and enters into his regular rounds of watching until 11.30, reaching home before midnight. The second man relieves him at this time, and watches until 6 A.M., when he eats his breakfast, starts the fire, and opens the factory for employees at 7. Having had breakfast and the factory open, he is ready to go to his workshop until noon, when he goes home, and returns at 11.30 that night. In this way the expense would be no greater than employing a sweeper or helper during the day and a watchman at night, and each would have one-half day and one-half night at home. It is plain to anyone that a man with these hours at home could get the requisite amount of sleep. Change about could be had each week, so that the man who had the first half of the night to watch one week could have the second half the next week. A man who works nights and sleeps days becomes a machine instead of a live man, and it is a common thing to find buildings badly on fire with the watchman taken out suffocated and nearly dead, and in many big fires which have occurred in buildings at night watchmen are known to have been employed. In the Pinkerton Watch Service the men go on at 7 P.M. and come off at 10; go on at 1 A.M. and off at 5. In the watch-tower fire service, from which an average of 400 alarms are sent out each year, the men are relieved every two hours, so careful are they that they must not sleep. Mr. Simonson's plan has been tried for the past two years in several large establishments, in which it has been found to give perfect satisfaction.

IT is a rule of many, if not all, insurance companies, in taking a risk upon a wood-working shop, that the fine dust which accumulates in great quantities upon the beams and joists overhead and elsewhere shall be periodically removed. They must be kept clean.

It has been shown by experience that this dust develops explosive qualities to almost as great an extent as that of flour mills. By ordinary methods the removal is attended with considerable labour, and in proportion to the amount of labour is apt to be the degree of neglect. At the Atchison, Topeka & Santa Fe railroad shops at Fort Madison, Iowa, compressed air is made to perform the task, with but little work. Air pipes, says the *Railway Age*, are run through the building overhead, and at intervals they are provided with fittings for the attachment of hose. Once a week a man is detailed who goes aloft and blows the air into every crevice and over every exposed surface. As a result, the timbers become as clean and free from dust as if the building had been but just completed. The improvement in appearance alone ought to be worth the trifling expenditure. The practice affords another, and a very neat, illustration of the many possibilities of compressed air service.

As a good illustration of the fact that the so-called wage-earning class gets about all the sympathy it deserves, one of the daily newspapers—the *Springfield Republican*—not long ago pointed to the case of N. O. Nelson, a prominent machinery manufacturer at St. Louis. Some years ago he introduced the profit-sharing plan into his factory, and since then he has divided up each year among the men the profits from the business, after deducting a certain amount for interest on capital. Recently he concluded to go even further. He determined to sell his factory to his workmen, letting them pay for it out of these profits voluntarily given them. They struck at once. They wanted no factory. If anything was to be given them, let it be money paid out every Saturday night. Mr. Nelson took them back on the old terms. We may possibly find in this attitude of the men, adds the *Republican*, a result of coddling. That is what profit-sharing without loss-sharing amounts to. Men who are given above their regular wages a share of the profits in good times, without liability to a share of the losses in bad times, are the recipients of a gratuity which they soon come to regard as their just due, and they naturally grow into the temper of an overfed subject of charity. Why, indeed, should they want the factory, with all its liability to losses as well as profits, when they now get the profits without any risk of loss?

Electro-magnets as lifting agents in connection with cranes came into use several years ago, though, on the whole, their employment in this way has been comparatively restricted. In one of the large English foundries—at Sandycroft—however, they are now again applied to that purpose, and in sizes which permit of readily lifting, by their means, weights of as much as two tons. The magnets are attached to a crane, and take a current of about 5½ ampères at 110 volts, controlled by a switch. Some measure of the service gained from these magnets may be obtained from the statement that with one of them three men can do in about fifteen minutes the work which previously occupied twice as many men for about an hour and a half.

An interesting lightning experience is recorded in the German paper *Glückauf*. It appears that at some iron works in an exposed situation near the banks of the Rhine the workmen had often reported that lightning seemed to strike the tops of the blast furnaces, and even enter them, instead of being attracted by the lightning conductor on the chimney, which is at a much greater elevahion. Though little credence was given to these reports, the men were instructed to keep a strict watch upon such phenomena in future. During eight years they stated that the furnaces were struck three times, while out of ten lightning flashes only one was attracted by the lightning conductor, the others chiefly striking piles of puddle bars.

On one occasion, however, Franz Büttgenbach was showing some colleagues over the works and was with them at one of the furnace tops when a flash of lightning struck the furnace, which trembled and rattled. The visitors and two furnacemen were stunned, but on coming to themselves they all declared that they saw a pillar of fire enter the furnace mouth. At the top of the furnace, however, nothing unusual was noticed, except that the thick coating of dust which covered the plate iron shield was driven off; but the men at the bottom reported that the slag, flowing from the furnace in a slow stream, had flowed more quickly for a little while, as when a furnace is tapped. They, too, considered that the lightning had entered the furnace because of its rumbling and trembling. The furnace was then carefully examined, but no damage was observed, nor any change in its working. The next cast of metal also appeared normal, and analysis of the pig revealed no change in composition.

Herr Büttgenbach, in communicating his experience to *Glückauf* of Essen-on-der-Ruhr, observes that he could now believe the men's former declarations that such phenomena were repeated at two of the furnaces every year, but always without leaving any appreciable trace behind. He considers that the reason the lightning entered the furnace, instead of being attracted by the lightning conductor, was that a compact pillar of smoke containing much water and dust rose to a height of 100 feet above each furnace mouth, forming a good conductor of electricity, which must have passed through the furnace charge, out of the pig bed and into the earth without doing any damage; but he regrets that the pig of the cast immediately following the lightning discharge was not examined under a microscope, which might have revealed differences of structure as compared with normal pig iron.

Two theatre cars are the latest adjuncts that have been made to one of the electric street railroads in the city of Brooklyn, N. Y., and point in quite a new direction in which profitable business may be found for the "trolley." It is thought that the cars will be chartered for private theatre parties, sight-seeing trips about the city, luncheons or long trips into the country. Arrangements have been made with the other companies operating trolley cars in Brooklyn to allow these cars to run over their lines, so that it will be possible to go to any point in and around the city. The cars may be hired for an hour or a day, the cost ranging from about $20 (£4) upward. They are twenty-five feet long over the body and thirty-six feet long over the platforms. The latter are enclosed with railings with bronze trimmings, and with solid bronze posts supporting the hoods. The windows of the cars are furnished with plate glass, and the inside is of mahogany, handsomely carved and finished in oil. The windows are supplied with tapestry curtains and silk velour draperies of the most artistic design. In each of the four corners of the car there is a buffet, with lockers above and below. The doors of the car are of the double automatic pattern at each end. There are three incandescent electric chandeliers in each car, with an incandescent gooseneck bracket over each buffet, and electric heaters under the seats contribute the warmth necessary for comfort. The seating is of loose wicker chairs, and so made that the cars cannot be marred, as all the points that are liable to come in contact with the sides of the car are handsomely upholstered. The floors are carpeted, and each car also is supplied with two tables, which may be attached to the sides at different places.

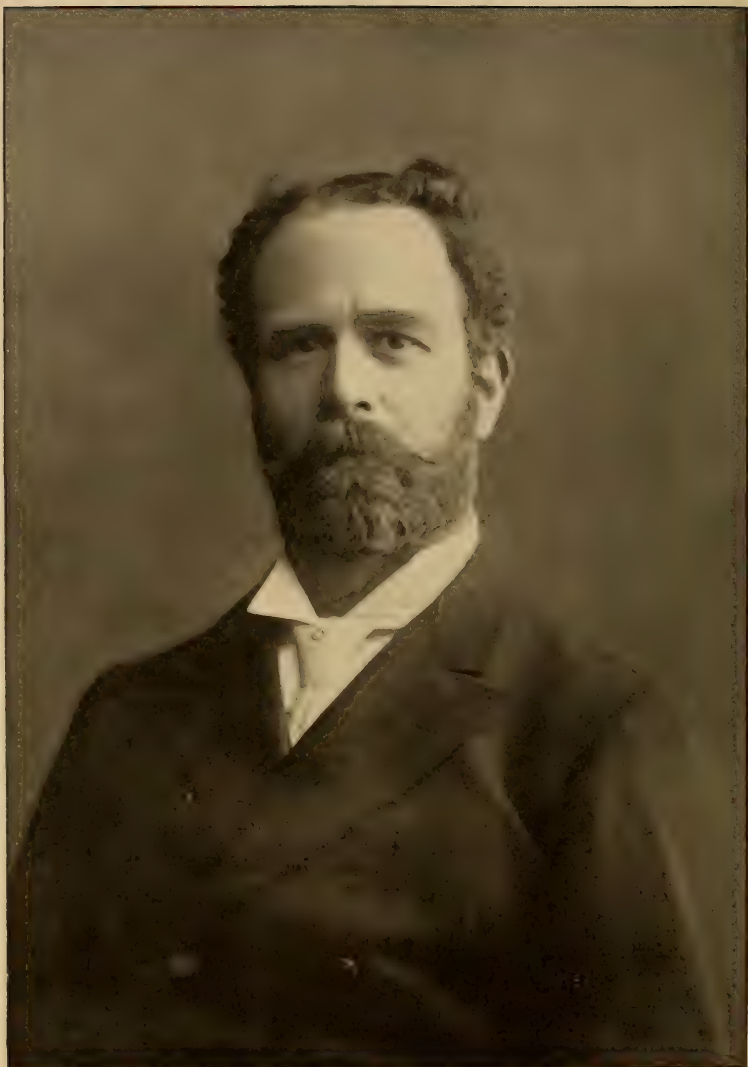


PHOTO BY J. BACON, NEWCASTLE-ON-TYNE.

Yours faithfully

Thomas Mudd.

General Manager of the Central Marine Engine Works, West Hartlepool, England.

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SUGAR-MAKING MACHINERY IN CUBA.

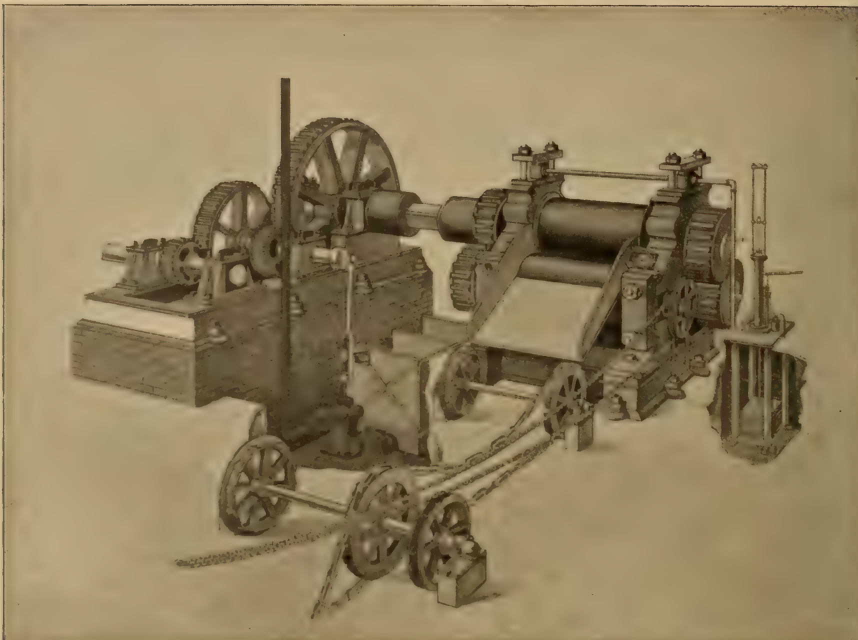
By A. W. Colwell.

THE present condition of affairs in Cuba is directing attention to that unfortunate island, the situation being one that demanded an appeal to arms. Taxation without representation ; condemnation without trial; confiscation without cause,—these and various other oppressions have caused the Cubans to take up arms again, placing the island in a chaotic state of war, completely stopping business and interfering with the engineering profession as much as with any.

Prior to the reciprocity treaty with the United States, the latter had an export business with Cuba amounting to about \$9,000,000 (£1,800,000) per year, and received about \$40,000,000 (£8,000,000) worth of sugar. During the reciprocity treaty the American export trade with Cuba amounted to \$27,000,000 (£5,400,000), the addition being principally in machinery, to the detriment of European houses. The abrogation of the reciprocity treaty, however, and the war in Cuba have reduced the American export trade, till, at the present date, it amounts to hardly \$5,000,000 (£1,000,000) per annum, and that in bread stuffs, with hardly any prospect of improvement until the end of the war. Then, the ruined and injured machinery of the sugar houses will have to be re-installed. How much the United States will get depends upon the conclusion of the war ; if favourable to the Cubans, there is no reason why the exports of the United States to the island should not reach \$50,000,000 (£10,000,000) per annum.

Twenty-five years ago planters were receiving from five to six cents (2½ to 3d.) per pound for their sugar, delivered in hogsheads at their plantations. In those times of slavery and high prices but little attention was given to machinery or engineering. Planters were content to get what tonnage of cane they could from an acre of land.

The cane was brought to the sugar house where the labourers slowly put it on the carrier, passing it to the mill, where it was rolled or ground between the rolls of a three-roller mill to extract the juice, getting an extraction of 55 per cent. out of a possible 85 or 88

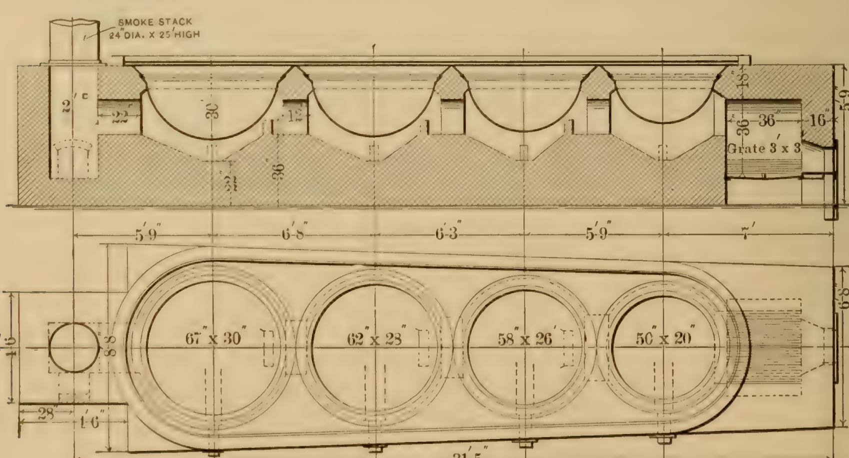


A CANE MILL WITH COMPOUND GEARING, JUICE TANK AND PUMP.

per cent. of the whole weight in the cane.

The juice was then run into a "Jamaica train," which was a set of four or five kettles set in brick work, having a strong fire under the smallest or "strike" kettle. The flames passed under and around all the kettles, the unconsumed gases escaping through a chimney. The combustion was so imperfect that at night flames could be seen many feet high, coming from the top of the chimney.

The largest of these kettles received the raw juice, and there it was limed and skimmed as the impurities rose. It



SECTION AND PLAN OF A JAMAICA TRAIN.

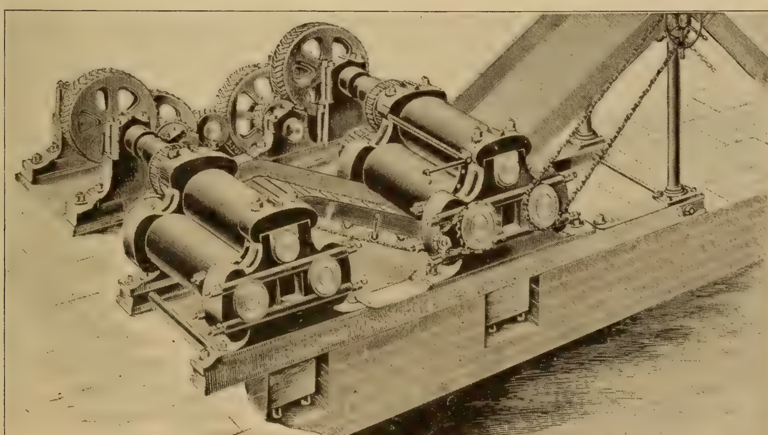
was then ladled to the next kettle in succession, each time being thickened in density and reduced in bulk by evaporation until it arrived at the "strike" kettle, where a skilled attendant knew the exact point at which to stop the fire and ladle out the mass into the crystallising pans, in which it was allowed to cool.

In a few days it was firm enough to be taken out, placed in hogsheads, and allowed to drain in the store-houses, losing at least one-sixth in dripping molasses. The hogsheads were then re-packed and placed on carts and drawn many miles to the railroad for shipment to the merchants' stores at the sea-coast, where they were again allowed to drain, were re-packed, re-weighed and sold, thus piling up an expense account that made the profits look slim ; but as sugar was selling at a high rate, these expenses could be borne.

I mention this operation of Muscavado sugar making to show that the engineers' duties were very light,—nothing to care for except the mill engines, the boilers and a few pumps. The buildings were low, wooden structures, without sides, excepting around the draining room, with a Spanish tiled roof. Fire was much to be dreaded.

Another important source of expense at the plantations was the fuel account. Coal being out of the question as it was worth \$8 (£1 12s.) a ton at the seaport, and \$12 (£2 8s.) or more on the plantation a few miles inland, only a little was bought for the blacksmiths. The natural fuel was the dried cane trash or "bagasse" which was received wet into carts directly from the mill, and carried to a field, prepared like a brick yard, by pounding clay smooth, slightly on an incline so that the excessive rains would run off. There the bagasse was dumped, spread and turned, to be dried like hay. It was then gathered by a board, shaped like a road-scraper, and drawn by oxen to the Jamaica trains and boiler fires, where men gathered it in armfuls and pushed it into the open door to keep up the fires.

The handling of the fuel necessitated a large number of men, women and children, and the attendants at the boiling kettles were constantly calling out for more fuel, which, if not forthcoming, the under-foreman would urge along with his whip. But this was not enough ; thousands of cords of wood had to be cut during the dead or summer season and drawn to the sugar houses to supply the shortage of bagasse. The whole presented a



A CANE MILL AND BAGASSE REGRINDER.

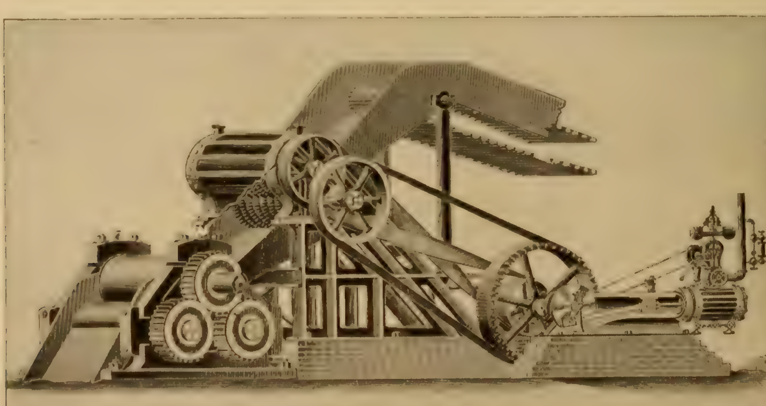
scene of noise, steam and activity that made the old-style boiling house a thing to be remembered. From the outside, black smoke could be seen pouring out of the chimneys,—a sign of imperfect combustion,—while the exhaust steam from the high pressure cane engine was blowing into the air, so that for miles away it was known whether a plantation was working or not.

This method of making sugar was most wasteful and extravagant. From 110 to 140 lbs. of sugar to a ton of cane were considered an eminently satisfactory result. Sugar houses, like those just mentioned, could be seen on hundreds of plantations; but all is now changed. The abolition of slavery marked an epoch in labour that compelled the planters to count the cost. At present, the field labour in Cuba is paid as well as in the United States, for example, good experienced field hands getting from \$35 (£7) to \$50 (£10) per month. Living is much cheaper than in the sugar districts of Louisiana.

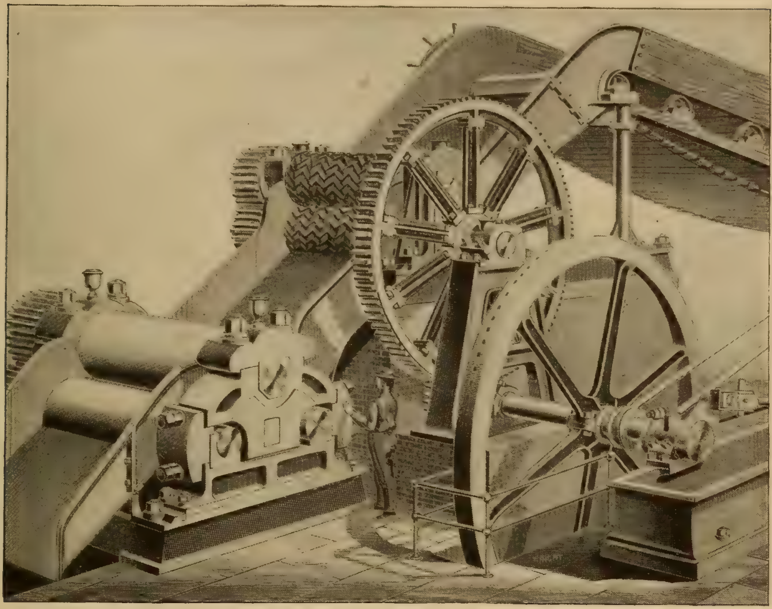
Means had to be devised to save labour and fuel, and to extract more juice from the cane, since one could not get more from the land. The engineer was called upon to get the greater quantity of juice. The mill was pushed to the breaking point, strapped up, and put at it again. More powerful and larger mills were ordered, and quick-moving engines with the latest cut-offs were employed. The extraction was thus much improved, but not enough. A still larger second mill and engine to re-grind the bagasse was installed, so that the extraction could be increased.

The labours of the engineer began to grow. More and larger engines and mills were put in, with trains of gearing, many plants weighing as much as 300 tons. Accidents accumulated,—broken spur wheels, twisted shafts and cracked rolls, due to the hasty feeding of the cane. A car coupling or crowbar, passing with the cane into the rolls, would cause much damage. A remedy had to be found, and it was in the way of a hydraulic governor, invented by Mr. McDonald, of New Orleans, La.

This governor was applied either to the caps that held down the top roll, or under the bed-plate. The action was such that when a foreign substance came between the top roll and the bagasse roll, the former would raise and allow the obstruction to pass through without breaking the mill. The governor also served another valuable purpose by exerting a uniform pressure on the cane. Notwithstanding that there might be great inequality in the feeding of the cane, the 400 tons pressure was constant; whether they were sending it in two canes deep or whether it was twenty canes deep, the pressure was always the same, and by that means a much better extraction



A CANE SHREDDER.



A CANE CRUSHING MILL.

was secured, regardless of the volume which passed through.

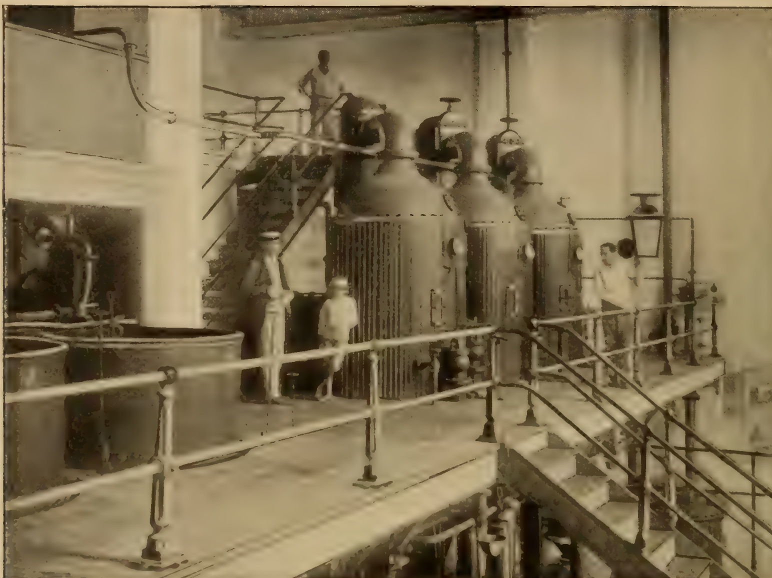
At times, when cane was fed irregularly, it would slip at the entrance of the rolls or ball up on the knife between the rolls, causing a world of trouble to the engineer and necessitating the backing of the engine, loss of time, and driving ahead at full speed, and also multiplying the chances of damage.

A device, called a cane shredder, was next invented. This, as its name indicates, tears the cane into shreds of varying lengths, perfectly opening it, thoroughly breaking the joints and leaving a pulpy mass, in the most advantageous condition to allow the mill to thoroughly press out all the juice. Of such shredded cane the mill would take a much larger supply than when it was fed whole. The mill did not choke, it was not necessary to stop or back the engine, and the time was saved which heretofore had been lost in stopping and backing the mill. With the shredder the quantity of cane which the mill can grind is increased 30 per cent.,—sometimes even as much as 75 per cent.

No more steam power is required to operate the shredder in connection with the mill, than would be required for the mill when grinding whole cane. Cane shredded in this machine is in a perfect condition to receive saturation after leaving the first mill, and it can also be claimed that it is in a superior condition for fuel for the bagasse furnace after it leaves the second mill.

A machine designed to accomplish the same result is the cane crusher which, though invented but a few years ago, has been adopted by a great number of cane sugar manufacturers, especially in Cuba, where it was first put to trial, and where it became extremely popular. The crusher not only cuts the cane but also presses out the juice and thus performs the double function of cutter, or shredder, and of mill. It never gets choked with cane. These crushers, when attached to cane mills, will increase their capacity by from 50 to 100 per cent.

The same advantages can be claimed for each of these types of preparatory machines. The only difference is that the shredder will put the cane in a finer



TRIPLE EFFECT APPARATUS ON A PLANTATION NEAR CIENFUEGOS, CUBA.

condition to receive saturation between the mills.

After the introduction of the vacuum pan, the Jamaica trains were used to reduce the juice to a thin syrup of 25 degrees Beaumé. This was passed to the vacuum pan to be crystallised, using the exhaust steam from the different engines and pumps.

There is a stage in the cooking of the juice that necessitates higher heat than can be had from exhaust, so that live steam has to be used. The employment of this was a great step, but not great enough. The Jamaica trains had to go. Steam defecation followed, with multiple effect. The cleaning and concentration of the juice was done entirely by steam.

To Robert Rileaux, a mechanical engineer of New Orleans, La., who died in Paris about three years ago, is due the invention of the multiple effect apparatus,—a remarkable steam saving appliance. It is considered one of the greatest fuel savers in the sugar business, as the initial heat entering into the first pan is used three times before it is passed to the condenser. Its operation is as follows :—

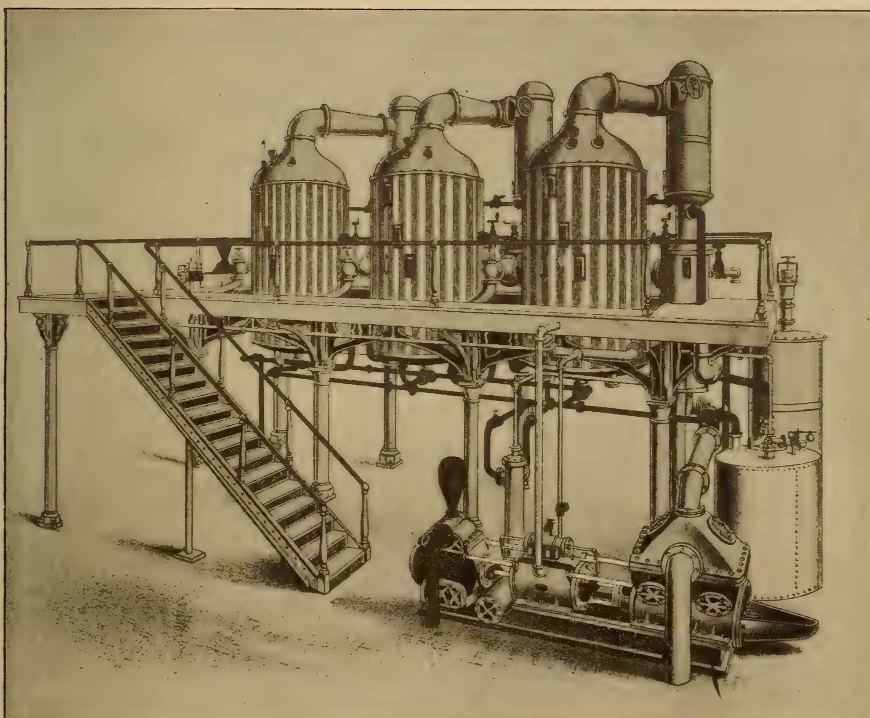
Exhaust steam at about 5 pounds pressure is admitted to the heating surface of the first vessel, the body of which, containing the sugar liquor, is under a vacuum of 5 inches and a temperature of 212 degrees F. Sugar liquor boils at 220 degrees, owing to its density. The vapours arising from the boiling pass to the heating surface of the second vessel, where the vacuum will be 17 inches and the temperature 180 degrees in the body of the syrup. The vapours there generated pass to the heating surface of the third vessel, where the syrup is under the still higher vacuum of 26 inches, with a temperature of about 140 degrees. The vapours generated in this body finally go to the jet condenser where they are condensed, the non-condensable gases and air being drawn off by a pump. By this apparatus an evaporation is accomplished that uses but a little more than one-third of the fuel which would be required if the evaporation were performed in the ordinary way.

Up to 1883 cane sugar held the markets of the world. After that the production of beet sugar in Europe began to exceed the output of cane sugar and

lower the price. A new condition of affairs stared the small planter in the face. He could not produce sugar at the low prices, and as he could not raise money to buy improved machinery, he was forced to sell his cane to his more fortunate neighbour, and become simply a planter.

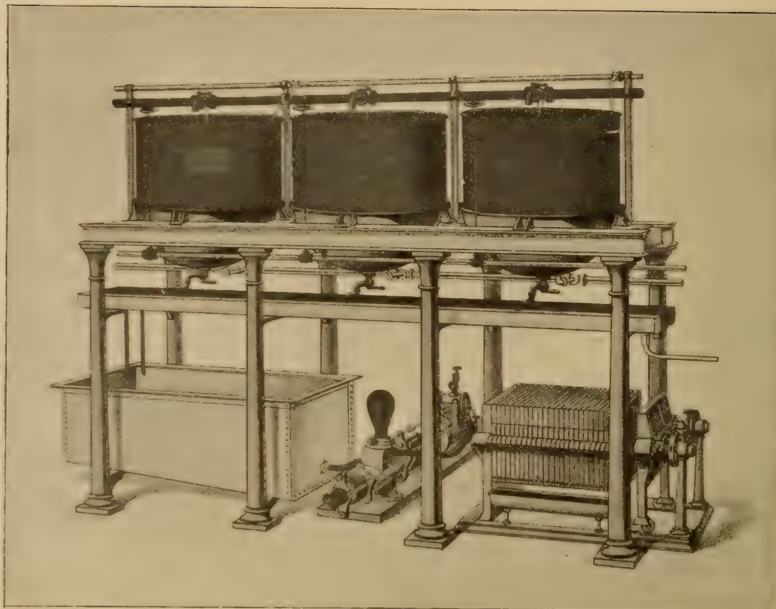
In this way was inaugurated the "Central factory system." This provided for the installation of the most improved plant in every respect in steam and labour saving appliances, getting the greatest amount of juice from the cane, and then extracting the largest amount of sugar from the juice. The old two-flue horizontal boiler, or no flue at all, gave way to the water-tube boiler, and the drying of the bagasse in a field was supplanted by a furnace for burning the bagasse directly as it came from the mill. This is now so well developed that the bagasse serves for all fuel required by the sugar house and a large amount is left over which some planters are trying to use as fertiliser.

Since Rileaux's time, the triple effect has been improved in form and arrangement, but not in principle. The vacuum pan has been enlarged and improved so as to boil five charges, of 120 bags each charge or "strike," in 22 hours, whereas the old-style pan would make only about two strikes of 50 bags in 18 hours. The handling of the "massecuite" as it comes from the pan has been much simplified. The centrifugal machine has been brought into play, into which a charge is received, the molasses purged off, and the dry sugar delivered into a bin, cooled and packed into bags, which will equal a barrel of refined sugar in weight, and delivered to the cars.



A TRIPLE EFFECT EVAPORATING APPARATUS OPERATED BY A HORIZONTAL PUMP.

The changes in Cuban plantation sugar houses is quite in keeping with



STEAM DEFECATORS WITH FILTER PRESS FOR TREATING SCUM.

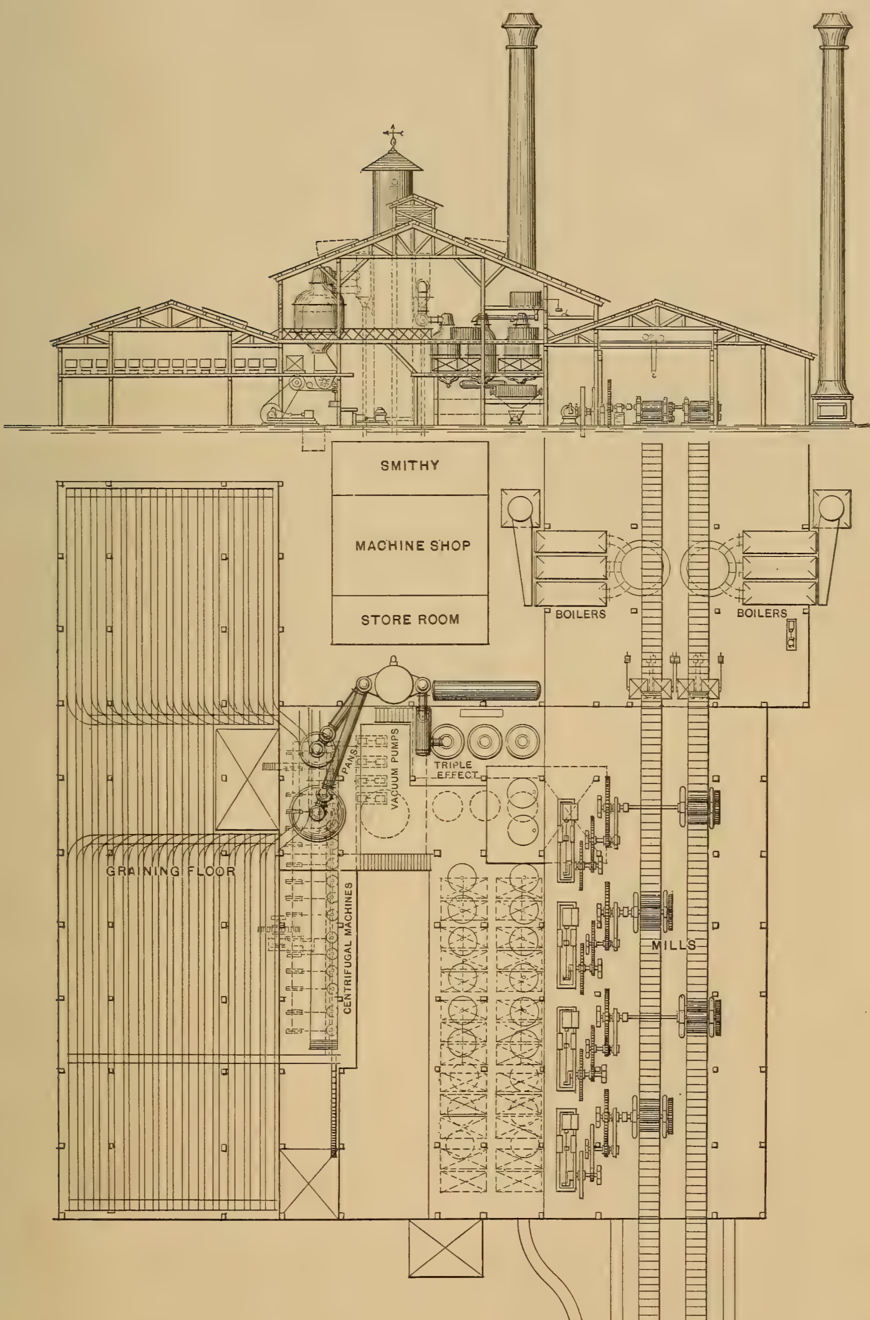
the improvements in sugar refineries elsewhere. The illustration on page 515 represents a typical plant, complete in every respect. The house is an all-iron structure, 160 ft. long, 76 ft. wide, with bays on each side, 30 ft. wide. All the platforms are of wrought iron as well as the columns, beams and floors, thus barring every possibility of fire.

On the right are two cane and two bagasse mills, operated by separate engines, with saturators between the mills. Four lines of railroad supply cane to the conductors at once. Every ton of cane is weighed. The bagasse from the first mill may be saturated before it enters the second, and, upon leaving the second, will be weighed. It is then passed to the bagasse burner, which is shown on page 516.

In this, after the bagasse has passed the first opening of water-tube grate bars, it descends from one series to the other, tumbling and mixing. After it leaves the first set of bars it is in flames, the combustion being aided by the blast tuyeres on the side, and the water contained in the bagasse is converted into steam. Owing to the intense heat, this steam is decomposed into its constituent gases, the hydrogen gas is burned and a complete and thorough combustion is obtained, more so than by any other method. The products of combustion pass constantly downward over the series of water-tube grate bars, and through and between the vertical water tubes of the boiler. By this system of burning, we get so complete a destruction of the bagasse that there is no great mass of clinkers to clog up the brick work, there being, instead, simply a fine dust.

The type of boiler presented is very simple in construction, setting and operation. The parts can all be put in a box car at the lowest rates of freight and any part of the boiler will pass through an ordinary door. At the rear of the boiler, in the breeching, may be placed an exhaust fan, drawing the spent gases through and delivering them to the stack.

We will now follow the juice. This is pumped from the grinding mills into two tanks and weighed, and the gauge Beaumé and the number of gallons are ascertained. With these factors, a



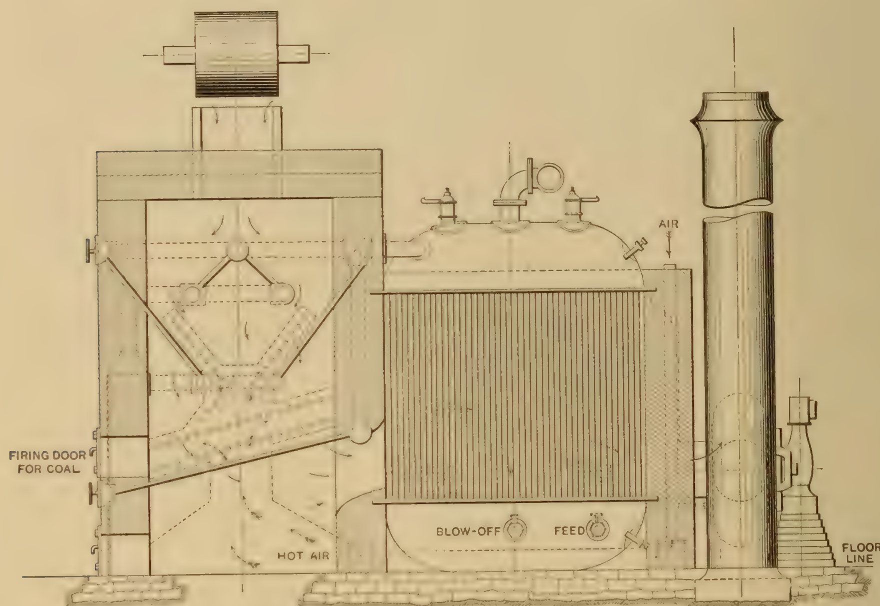
A SUGAR HOUSE DESIGNED BY A. W. COLWELL, NEW YORK, FOR AN OUTPUT OF FROM 800 TO 1000 BAGS A DAY.

chemical control of the mass is assured. The defecators are just below. The second juice tanks are just below the defecators, so as to deliver directly into the triple-effect apparatus. The skimmings from the defecators are received into closed defecators on the ground floor, where they are treated, and the product is pumped through filter presses. The clear juice goes back to the defecators again, while the filter press cake is received into dump carts and is delivered to the field as fertiliser.

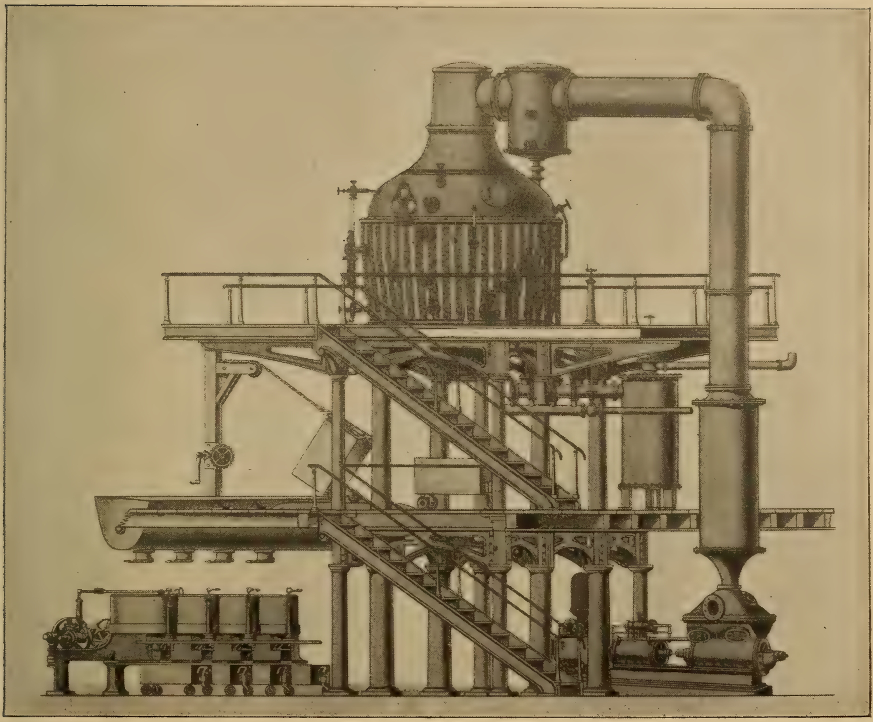
In the illustration on page 515 a triple effect is shown in full lines and a second one is shown by dotted lines. A 14 ft. vacuum pan and a 10 ft. vacuum pan, shown on the third story, are for sugar; the 9 ft. vacuum pan is for molasses boiling. The house is arranged so that the sugar can be purged hot as it comes from the vacuum pan, or cold by being discharged into the wagons, where it is allowed to crystallise in the graining room which is supplied with railroad tracks and turn tables. This graining or hot room is closed and partitioned, so that the temperature can be graduated as the "massecuite" ripens.

The mixer is arranged in two parts, so that first sugars and molasses sugars can be worked upon and centrifugaled at the same time. The molasses tanks are shown sunk in the ground. The centrifugals are just under and hanging to the mixer, with the driving engine in the middle. When purging cold, the bags can be attached to the centrifugal machines and filled directly from the mill. The first floor under the graining room is used for storage, with a railroad track outside the building for the full length of the house.

The illustration shows the house to be operated by independent pumps. There will be about ten of them, set in the open under the vacuum pan. Many planters prefer the beam pumping engine, which would be placed in the centre of the house and receive its various air, water, syrup and molasses connections of copper piping to and from the tanks.



A GREEN BAGASSE BURNER APPLIED TO A VERTICAL WATER TUBE BOILER.
DESIGNED BY A. W. COLWELL, NEW YORK.

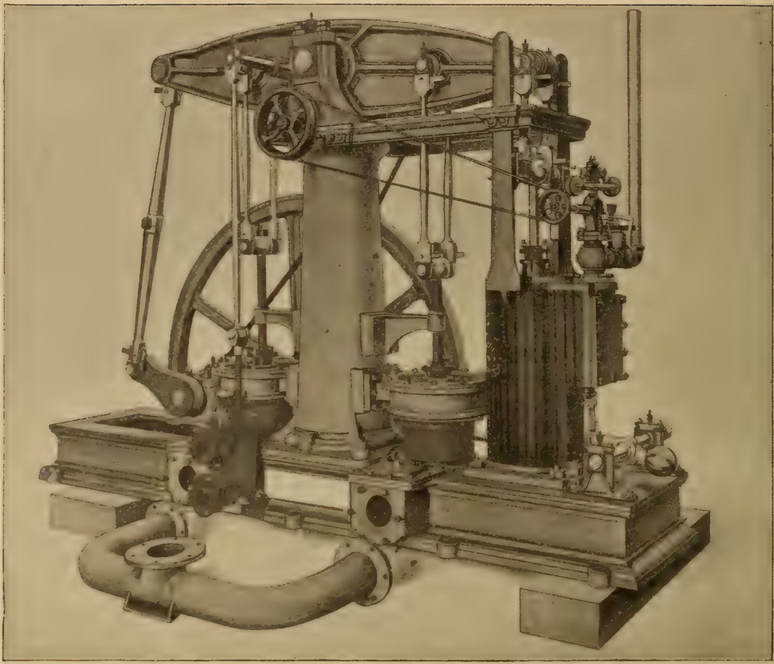


A VACUUM PAN SET ON TWO PLATFORMS, ARRANGED FOR HOT OR COLD PURGING.

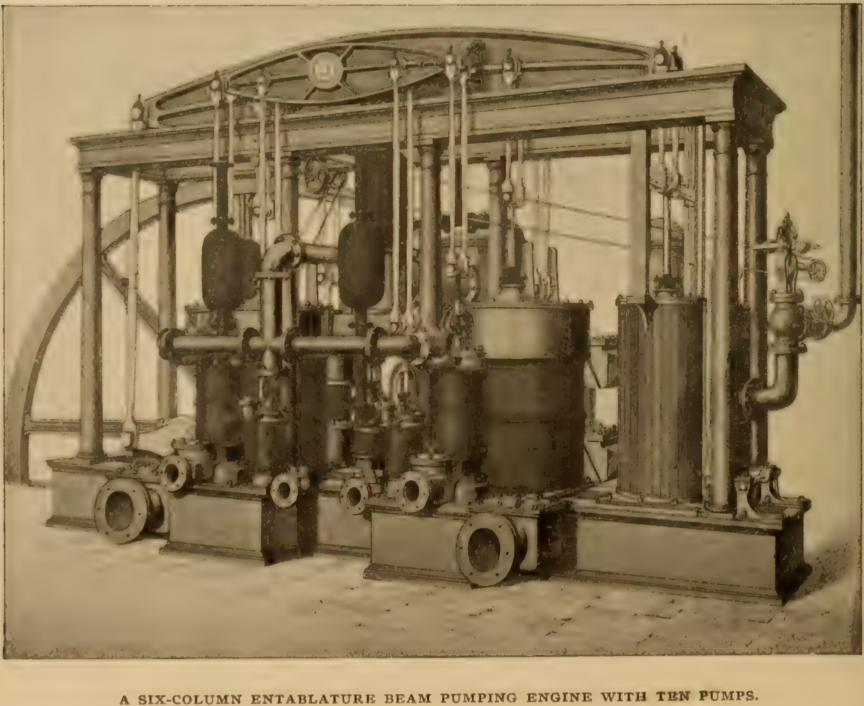
In the plant here shown there was no need for injection or cooling towers, as the plant would be located near the river where a pump would be established, delivering into a water tower, which is shown projecting above the roof, and serves to supply a small village as well as the sugar house. Upon this tower will be noticed brackets which support the condensers of the vacuum pans and triple effects. These condensers are of the well known counter-current type, which uses but a minimum of water while maintaining, with the proper pump, a high efficiency in vacuum. The water for condensation is allowed to run back into the river much below the point of intake.

A strong point is made in saving every gallon of hot water from condensed steam and returns from the vegetable vapours arising in the triple effect. This vegetable water is used in the boilers and acts beneficially upon the mineral waters obtained on the land. The exhaust steam from all engines and pumps is received in a tank, where it is separated from its grease and water, and is then passed to the triple-effect apparatus. If there be any surplus of this exhaust steam, it is utilised in the vacuum pan. Every hot pipe, whether steam, water or syrup, is covered to prevent radiation and save fuel.

From the vacuum pan platform the sugar master can see the workmen of every department and the operation of all the machinery. But few men are needed, as the passage of the sugars is as near automatic as can be arranged. As the men have the work in their department directly in front of them, there is no necessity to walk great distances to reach the different valves that control the different pipes. Fresh hot and cold water is convenient to all the departments for cleaning and other purposes. The lime for defecation is on the



A SINGLE COLUMN VACUUM PUMPING ENGINE.



A SIX-COLUMN ENTABLATURE BEAM PUMPING ENGINE WITH TEN PUMPS.

ground floor, where all dirt is confined and raised, as may be required, to the defecators.

The house is so set that the prevailing wind blows from it over the mill, preventing dust from entering; at the same time, the location is made suitable to the incoming cane cars from the field and the out-going loaded cars. All this comes within the province and duty of the mechanical engineer. How well he has performed his duty can be best told when we know that sugar can be produced for 1¾ cents (⅞d.) per pound. Every economy must be studied; every method and improvement must be considered; for, the up-to-date sugar houses are conducted with as much attention and ability as a well appointed establishment anywhere else.

The engineer has under his charge a plant that will match many proud business establishments in other countries. Many of the best plantations can show $1,000,000 (£200,000) invested in machinery and iron buildings. A few can claim a million and a half investment. Most of the important "Central" factories represent about $500,000 (£100,000) investment. These "Centrals" turn out from 500 to 600 bags of sugar per day of 120 days' working time, at the low price of $6 (£1.4s.) per bag, or a value on the crop of from $360,000 to $430,000 (£72,000 to £86,000).

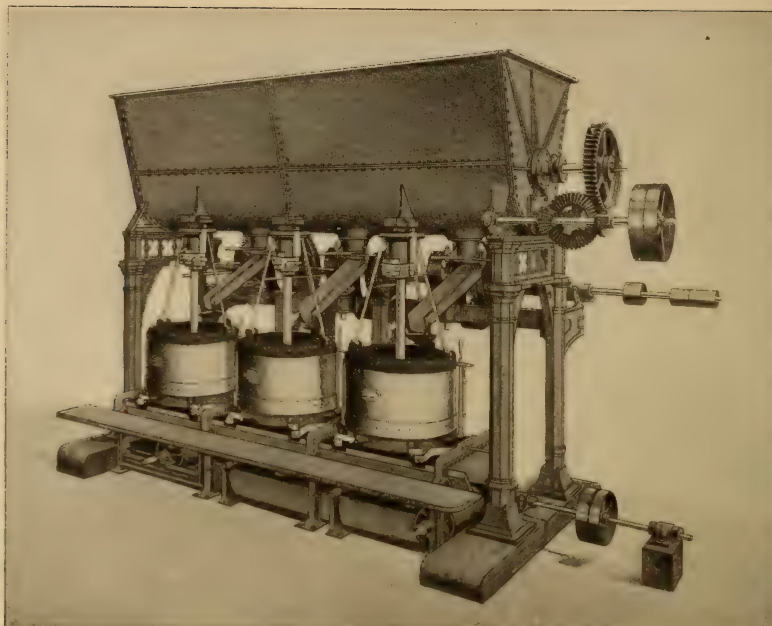
Most sugar houses have a switch from the main line of railroad directly into the house, so that the handling of sugar can be facilitated. This is now necessary, as many plantations are handling 100 tons of sugar per day. The following table, taken from an Havana journal, gives the number of Central Factories in the jurisdictions of the three principal districts in Cuba:

		No. of Factories.
West.	Vuelta de Abajo	30
	Havana	40
	Matanzas	--
	Cardenas	118
	Total	188
Centre.	Sagua	43
	Cruces	15
	Santa Clara	16
	Cienfuegos	32
	Remedios	20
	Trinidad	3
	Sancti Spiritu	7
	Nuevitas and Principe	6
	Total	140
East.	Manzanillo	14
	Gibara	6
	Guantanamo	11
	Santiago	8
	Total	39

These 364 factories produced a crop, in 1894, of 1,000,000 tons, and in 1895 of 875,000 tons, an average of 3000 tons per Central. It was but a few years ago that a 1500-ton plant was considered a large one; but the little plants have stopped grinding, and sell cane to the Central.

In the various steps here outlined the engineer has been the sole factor, for the chemical control of the houses can do nothing without perfect working machinery. The evolution from the Jamaica train to the vacuum pan and centrifugal machines; the abolition of the train and substitution of the steam defecators and multiple-effect apparatus, and a more perfect system of using up the units of heat in exhaust steam for boiling; the arrangement of the house, so that the transit of sugar is automatic and uninterrupted from the time the juice leaves the mill until it is in sacks, ready for the cars; the complete revolution in steam making plant; the saving of fuel, so that a well appointed house of to-day will turn out 100 tons 96 degrees centrifugal sugar with one-quarter the number of working people than would turn out 20 tons of Muscavado fifteen years ago; no steam escaping; no smoke to be seen; all this goes to make up the result of the engineer's work.

The installation of electric lighting in the sugar houses admits of running all night, lighting up the yard and cane carrier as well, and also the owner's house and the different offices about the premises. There are many types of dynamos and lamps from America, Germany, France and England. The same can be said of pumps and engines,



STRIKE MIXER AND CENTRIFUGAL MACHINES.

so that an engineer must be able to go from one sugar house to another and adapt himself to whatever he finds. Some planters will confine their pumps to one maker; others will have as many different pumps as there are situations, necessitating a variety of repairs and correspondingly taxing the engineer's ingenuity.

At present, some sugar houses have a well appointed machine shop that can be used for everything that may be required on the plantation. A few have foundries where brass work and small iron castings are made. All of these come under the engineer's supervision.

As Cuba is receiving machinery from Europe, the opportunities of comparison are better there than in any other country. There seem to be divisions or classes in which each nationality excels.

The English build a much heavier cane mill, larger shafts, and more massive pieces of work than other makers. I have seen a bed plate of an engine, 8 feet wide, 26 feet long, 2 feet deep, which had chipping strips on the top side for the columns. When these chips were faced off, all were the same thickness above the top member, showing a perfect casting without twist or wind.

The French excel in triple effects and vacuum pans, splendid copper work in defecators and piping, and in the general sugar-house plant, except mills and engines.

The Germans are a great deal the same as the French, but lack that extreme nicety. Neither nation have their machinery as strong as the English, nor do they build extensive mills and powerful engines.

The American manufacturer makes everything, from the mill to the weighing scales. The mills, beam engines and other machinery are not as massive as the English, because with the stronger American iron such bulk is not needed. For the horizontal independent steam pump, America certainly takes the lead. No nation can equal the Americans in Blake, Cameron, Davidson, Knowles, Deane and other pumps.

In the defecators, triple effects and vacuum pans, the American machinery

has, upon the whole, longer life. It is strong and graceful, and the arrangement of the heating surface admits of better circulation; the vapours generated are condensed more promptly, and altogether more work can be performed in 24 hours from a given diameter of pan than by any other class of makers.

The French prefer a beam pumping apparatus, to operate the entire house, or a horizontal arrangement, whereby several pumps are on the same bed plate. The writer has replaced some French pumping apparatus with beam pumping engines, and has re-modeled different European pans and triple effects in Spanish America to the planter's profit.

In some jurisdictions in Cuba there is a rivalry between different planters as to the utility of the apparatus on their plantation, according as it may be European or American, but, in general, the cost of producing a ton of sugar by American-built apparatus is less than with any other.

In the line of centrifugal machines, all sugar making countries look to the United States. The first centrifugal machine the writer remembers seeing, was as a child, when taken by his father to the foundry and machine shop of George B. Hartson, in 1849. He was making the Aspinwall machine,—an under-driven machine with solid bottom basket, the sugar being lifted over the top. It did not travel as fast as the present machine, and, naturally, could not do so much work. Only a few, if any, of these machines are in existence to-day in sugar making; a few are used in laundries and wool establishments for drying.

I might continue this article much longer, speaking of the improvements made in the handling of cane in the field from the old way of cutting and putting on bull carts, to the portable railroad track with its small cars, run to the sugar houses; or where the small cars were lifted on larger standard gauge tracks and delivered to the carrier and dumped; or, still another method where the load, in crates, is lifted off the bull carts in the field but a short distance from the cutting, placed upon standard gauge cars and delivered to the carrier, where the crate, with its load, is lifted upon a tilting table and dumped, according to the speed of the carrier, so as to deliver the load from 15 to 20 inches thick, the canes all running straight as a lot of lead pencils, and so delivered to the shredder or crushers, preparatory for the mill.

Various methods of defecation, various types of triple effects, horizontal, vertical and sectional, and devices for checking entrainment, different types of apparatus for treating the massecuite, different methods of treating the molasses or wagon goods, chemical control of the house, etc., might be treated of, and a great deal more might be said about filter presses, their savings and advantages; in fact, a magazine article of this nature can only touch upon a few of the principal points.

ELECTRIC METAL HEATING AND WORKING.

By Joseph Sachs.

WHENEVER an electric current is generated, transmitted or transformed, the electrical energy used in overcoming the resistance or friction of the current-conducting medium appears as heat. Generally, this heat represents a loss, since the object may be to produce a different form of energy. In such cases it is important to minimise the electrical energy thus dissipated by making either the resistance of the current-carrying conductor, or the current itself as small as possible.

Rather the reverse of this is, however, the case with the electric light in which the useful illumination is a resultant or by-product of the heat produced by the current flowing through the high and concentrated resistance of the electric arc, or the carbon filament of the incandescent lamp. In fact, the electric current is converted into heat units which, being concentrated, bring the medium acted upon to the temperature of incandescence with the consequent production of light.

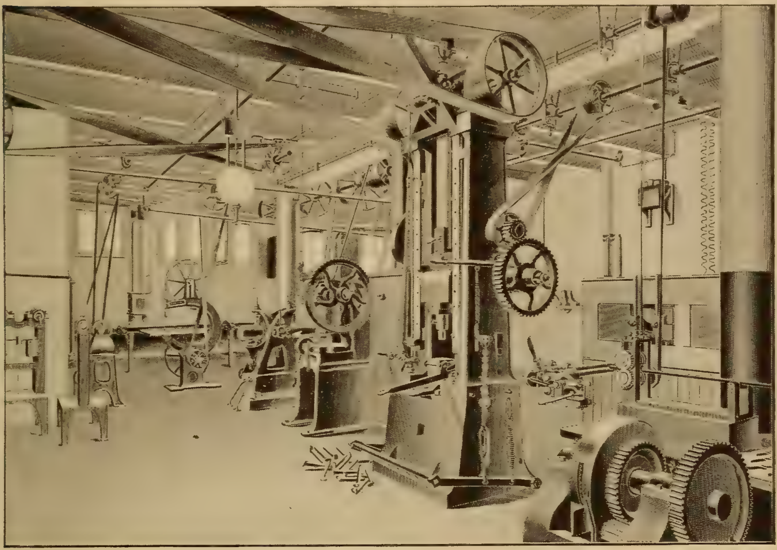
The principle involved is the same as that utilised in any transformation of the electric current into variously applied heat, the latter being in such cases, the useful instead of the waste product. Each watt of electrical energy will yield only a certain number of heat units, varying in exact proportion with the energy spent, or, stated differently, varying as the square of the current and directly with the resistance of the conductor. The striking feature is the variety of ways in which the heat units from this energy can be utilised to produce different temperatures in the medium acted upon.

Transmitting a small current over a long transmission wire necessitates a certain amount of electrical energy and produces a number of heat units in the conductor which are readily radiated from its surface and produce probably no appreciable increase in its temperature. By using a very large current, however, and a correspondingly low voltage, but still transmitting the same amount of energy, we can produce a red or white heat in short sections of copper, brass, iron, steel or other metallic rods or bars, or we can, by using an intermediate current and voltage, produce the intense and concentrated heat of the electric arc.

The heating effect of the electric current for metal working and heating purposes generally, has received special prominence within recent years. For these purposes high temperatures are essential, generally necessitating the use of large currents directly conveyed through the object to be heated, or the indirect application of the current through the medium of the electric arc, the heat of which can be imparted to the metal in various ways. Modifications and combinations of both have found applications. We shall here consider the applications to metal working, such as forging and welding, in which directions the electric process has not only cheapened, facilitated and improved former difficult operations, but has made many new ones possible.

Probably the simplest method of utilising electric heat for metal working operations where the objects are of fairly even cross-section is to send a current, sufficient to produce the necessary heat, directly through the metal and then work the latter in any manner desired.

For practical work, currents of very large volume and small voltage are used



A SHOP VIEW IN THE WORKS OF THE ELECTRICAL FORGING CO.
AT BOSTON, MASS., U. S. A.

since the resistance of the metal worked upon is very low. Such currents are readily produced by means of an alternating dynamo and transformer, the latter changing the comparatively small current of the dynamo to one of much greater quantity, but correspondingly small voltage. The heating transformer can, therefore, be located directly at the work and the dynamo at any reasonable distance. The use of direct currents would be impractical on account of the difficulty of commutation and transmitting the large currents necessary.

Various intensities of current are necessary to bring a cubic inch of iron, copper or brass to a welding temperature, but the time of application varies inversely as the current, and, therefore, the energy necessary, with slight exceptions, is very nearly the same in each case. Enormous current densities are required, that for copper per square inch reaching about 50,000 or 60,000 ampères. It is desirable, in view of this, to generate the alternating current at a low frequency (in practice about 30 to 50 cycles per second) to minimise self-induction.

Rods or bars to be worked are connected across the secondary terminals of a large heating converter, and when raised to the proper temperature, may be rolled, bent, forged or worked in any desirable fashion. Special machines are used in which the metal is heated by the current and fed to the machine at the same time. For making coiled springs a revolving roll or mandrel is connected to one terminal, the metal rod is fastened to it at one end, and passes between heavy contacts several inches from the roll and connected to the other terminal of the secondary. The different portions of the metal between the roll and contacts are successively heated by the current and the rod is gradually coiled. Modifications have been adapted for coiling pipe, bending rings, etc.

In another machine, by fastening one end of a rod, bar or strap to a fixed, and the other to a rotating contact clamp, the metal can be given any number of twists or turns when a current is passed through it and the clamp is rotated. In a similar fashion the metal can be bent into any shape by a suitable arrangement of fixed and movable

clamps. For forging, a machine has been devised in which a metal billet is rigidly clamped to one terminal, while the die forming the other is brought in contact under suitable pressure, heating the metal and shaping it.

After heating the metal as above it may be tempered or annealed. For such purposes the direct application of the electric current makes it possible to produce the most exact results. An important application is the local annealing of highly carbonised steel armour plates like those used for battleships, when it is desired to drill or otherwise work them after having been tempered. It is impossible to work such metal with ordinary drills or tools, and it was, therefore, of prime importance to find some method of locally softening it. The direct application of large electric currents, passed through sections of the plate wherever annealing was necessary, has solved the problem.

The apparatus for this purpose, as developed by the Thomson Electric Welding Company of Lynn, Mass., U. S. A., consists of an alternating current dynamo, generating 300 volts and about 100 ampères, exciter dynamo, regulators and the portable annealer weighing about 1000 lbs. and consisting of a combined transformer and contact devices. At the transformer the voltage drops to about 2 to 3 volts and the current is increased to about 10,000 ampères in the secondary, which is simply a large slotted copper casting encasing the primary. Large copper contacts are attached to the secondary and are cooled by water circulation. The actual contact between each and the armour plate is only ½ square inch, making a current density of 40,000 ampères per square inch of contact. The heating is greatly dependent on this fact. In operation the annealer, which is adjustably supported, is placed in position with the secondary contacts touching the armour plate on each side of the spot to be annealed. The current is then started and gradually increased until the spot reaches a dull red heat, after which it is slowly decreased to prevent rapid cooling.

AN ELECTRIC WELDING CAR.

For annealing large surfaces, a special machine has been devised in which one of the secondary contacts is reciprocated. Local tempering of soft steel or iron masses is equally feasible with the above apparatus.

Electric riveting by the application of similar principles has as yet found little practical application, but will probably be more generally adopted in the near future. Heating the rivets previ-

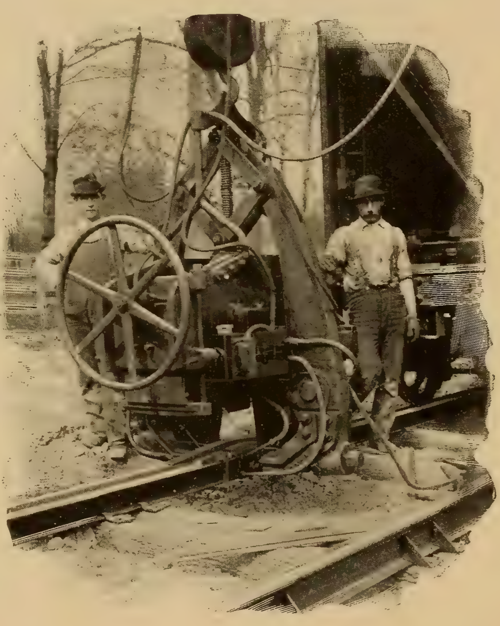
ous to insertion can readily be accomplished, but the operation would be greatly facilitated if the heating and upsetting could both be accomplished after insertion. Machines for this purpose have been constructed, and consist generally of a hand or power riveting press or hammer slightly modified, so that the riveting dies act as terminals of the converter secondary and, when brought in contact with the ends of the rivet, cause the current to flow through it, first heating and then, by the necessary pressure, upsetting the end. The head of the rivet may have a good contact and the other end a poor connection, concentrating the heat at that point, or the rivet may be slightly insulated from the plate by oxide.

Welding abutting metal objects by passing a current from one to the other through the contact and applying pressure when sufficiently heated is another development due to Prof. Elihu Thomson, who first patented this process which has found a great variety of applications. It is used by a large number of firms for welding wire, cables, rods, shafts, axles, rails, frogs and switches, uneven malleable castings, pipes and elbows, wheel tires and spokes, bicycle frames, metals and alloys of different composition.

The current is generated by an alternator, self or separately excited and controlled by suitable rheostats or choke coils. The welding transformer is mounted on a suitable base and has large contact clamps, directly attached to the secondary castings or rings, and various clamping, pressure and auxiliary devices are part of the welding machine. For very small work the transformer is not used, the clamps and pressure devices being placed directly on a small heavy current dynamo. Pressure for forcing the metal together after being heated, is produced by an arrangement of knuckles, levers, screws, springs, or, in large machines by hydraulic or pneumatic pressure devices connected to one or both clamps, which are arranged to move on heavy slides. In some large apparatus a total pressure of 50 tons can be reached.

By a suitable arrangement of automatic pressure, clamping and electro magnetic switching devices the welding operation is accomplished practically without attention. Such automatic welding machines are used principally for small work. Another machine is arranged for a general variety of welding work, and is therefore provided with various detachable clamping devices, so that bars and rods may be clamped and worked as desired. Other machines are arranged for one particular class of work.

Electric welding apparatus is also quite extensively used for welding wheel tires, spokes, wagon and carriage axles and other parts used in carriage and wagon-making. In butt welding the ends of hoops or rings, the current di-



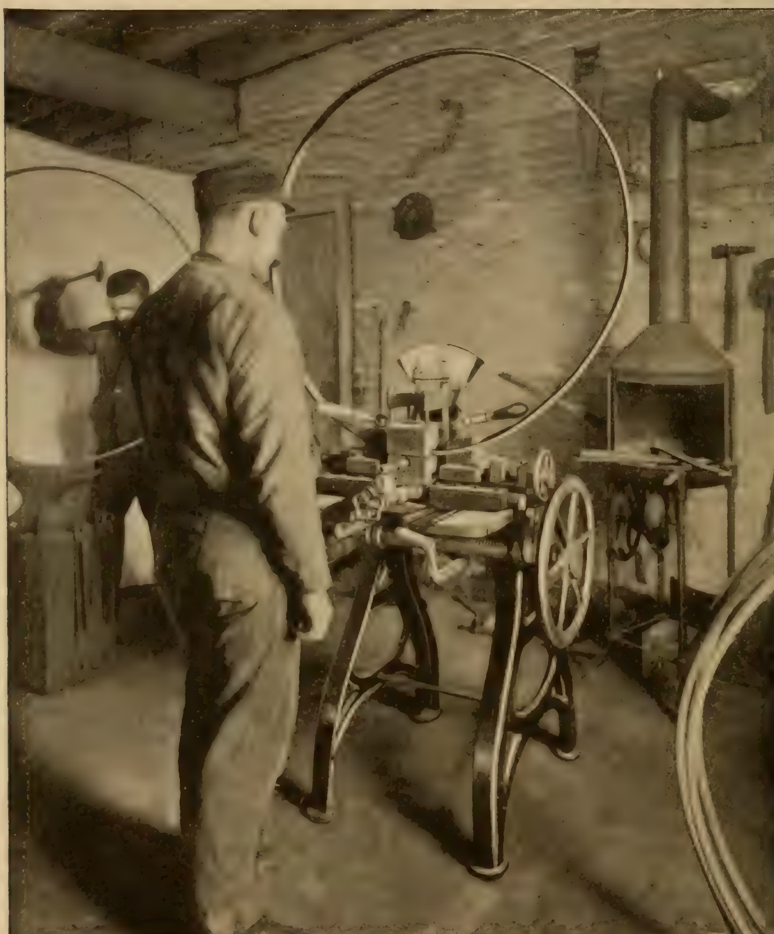
THE WELDING APPARATUS AT WORK.

vides, part going through the weld and part through the other portion of the ring, but the latter path being of comparatively high resistance, minimises the current going that way. Drills, reamers and taps consisting of a cutting part of high-grade tool steel, and the shank of a different grade, are easily

welded together. High grade armour-piercing projectiles in which the point and body are of different steel are also successfully manufactured by this process.

The welding of rails, frogs, crossings, rails to chairs and switches and similar operations is probably the heaviest work now done by electrical means. Welds up to 15 square inches are made, and a single weld of from 45 to 50 square inches has been produced. The laying of tracks electrically welded on the spot was recently described in this magazine. The boiler, engine, dynamo and welder are carried on a suitable car. The latter is placed in position by a derrick on the car and unites the rail sections by welding two chucks or lugs to the abutting ends.

An important element in the Thomson welding process is the abutting contact, whose comparatively lower conductivity locates the heat at this point. When pressure is applied, the metal is slightly burred or upset at the joint, but in some larger machines this is hammered down by suitable devices attached



A COFFIN TIRE WELDER IN OPERATION.

WELDING FLANGE HEADS IN STEEL CYLINDERS BY THE COFFIN ARC SYSTEM.

to the welder. In large machines heat conduction is prevented by a circulation of water in the clamps.

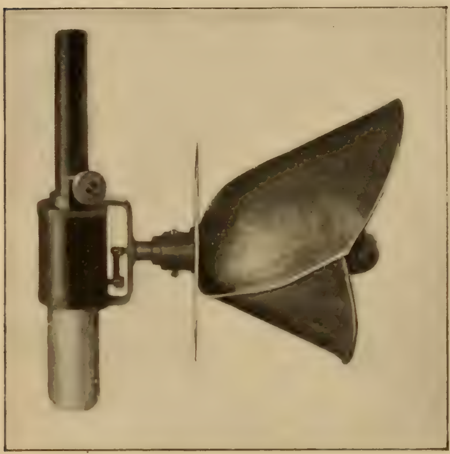
Electric brazing or soldering of rods or wires can also be accomplished by similar methods, but without the end pressure arrangement. The ends are brought in contact, current is turned on, heating the junction, and solder is fused at the heated ends and joins them.

A particularly noticeable feature in the application of the direct heating effect of the electric current is the internal heating of the metal in contradistinction to the external heating of the forge fire or furnace. In practice about 75 per cent. of the energy of the electric current is used in heating the metal.

The electric arc constitutes the most important of the indirect electric metal heating and working processes. An arc, between two electrodes, one of which may be the object to be worked, is the heating medium. A direct current dynamo or storage battery is generally used, furnishing about 100 or 125 volts and operating the arcs in multiple. When the metal to be heated acts as one electrode, its polarity depends upon its composition. The metal heating and welding arc is much larger and longer than the ordinary lighting arc, necessitating larger voltage and current. Whether large or small, however, the temperature of the arc is fixed, and for different work only the volume of heat developed can be regulated by varying the current. The temperature has been variously estimated at from 8000 to 12,000 degrees Fahrenheit.

The Bernados method of arc metal working was one of the earliest to be commercially developed and applied. The metal to be worked is connected to one wire from the generator or battery, and an arc is formed between it and a

separate movable carbon electrode connected to the other wire. This method is particularly adapted to surface welding of long seams or joints, the edges



THE COFFIN HAND TORCH ARC WELDING TOOL.

of plates or straps, flanges to pipes, and uneven material. The arc is formed between the seam, joint or abutting ends of the metal objects and the car-

AN ARC WELDING TOOL IN OPERATION.

bon electrode, bringing the metal at this point to the fusing temperature. No pressure is therefor required, permitting various operations to be successfully accomplished which would otherwise be exceedingly difficult, if not impossible.

Another important application is the refilling of blow-holes in defective castings, and the welding up of fractures. For this purpose a piece of similar metal is melted in the arc between the carbon electrode and the defective spot and is deposited where needed. In a similar manner broken parts, as, for instance, a gear tooth, may be reconstructed if a suitable mould be placed around the spot. Large objects must first be heated, otherwise the new metal will break away in cooling.

It is possible to utilise the heat of the arc without in any way making the object to be worked part of the circuit. An arc between two separate carbon electrodes may be used to heat or melt metal in contact with it. A magnet, placed with its field at right angles to the arc, will produce a blow-pipe effect on the arc. An arrangement of this kind consists of two converging carbons in a triangular frame and handle and an electro magnet connected in series with the arc with its poles set close on each side of the arc. This apparatus has found various applications.

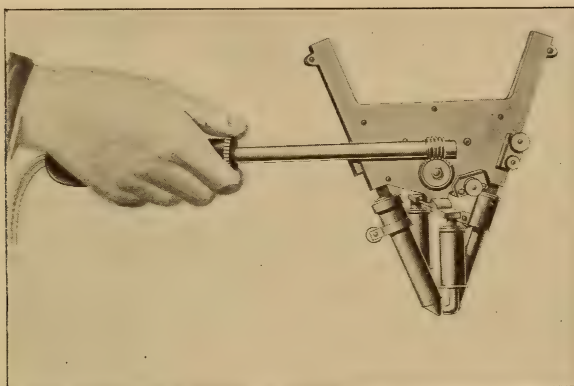
In the United States Chas. L. Coffin has paid particular attention to the development of arc metal working. The Coffin hand arc heating and welding tool is a form of arc torch. It consists of two concentric carbons attached to a suitable handle, an inner ½-inch rod and a larger surrounding cylinder within, or surrounding, which is placed an iron core, the winding around it being connected in series with the arc. The arc is rotated around the central carbon, and this arrangement, in addition to the blow-pipe effect, enables a large surface to be covered. The inner carbon is, in some cases, omitted, the arc being struck between the metal and the end of the carbon cylinder around which it rotates. Such torches are used for welding, boring and general heating and melting.

The same inventor has developed a method of heating by the radiated heat of the arc which has been used for welding tires, axles, etc. The arc is

enclosed in a heavy casing which confines the heat. After the objects have been clamped and brought together, a single movement opens the box, inserts the work in close proximity to the arc and closes it again and end pressure can then be applied. Automatic devices prevent overheating.

For longitudinal welding of pipes and plates an arc is struck between carbon electrodes on each side of the welding seam, the electrodes or the metal being reciprocated in the direction of the seam. An interesting butt welding method for plates, pipes, bands, etc., consists in rigidly clamping the metal on each side of the weld, heating it by the arc in any manner above described, and allowing the expansion to force the ends together. Machines for punching or riveting are provided with a movable electrode acting with the metal in creating an arc wherever necessary, to heat the rivet or sheet previous to punching or upsetting.

Soldering irons can be heated by resistance wires, placed within a hollow copper head, but there again the arc can be efficiently applied. The copper head is made to form one electrode and a movable carbon rod projecting through the handle, the other. Striking an arc between the two, brings the soldering copper to any desired temperature in a very short time. Ordinary sizes of such irons take about 50 volts and from 4 to 5 ampères. Another arc welding process consists in striking an arc between two metal electrodes, and when sufficiently heated, forcing them together. This method may be used where no great strength is required.



ARC TORCH FOR ELECTRIC WELDING AND SOLDERING BY DR. ZERENER'S PROCESS.

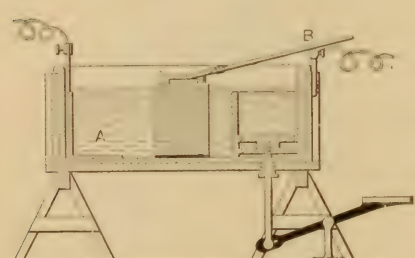
In all arc welding methods it is necessary that the operator's eyes be protected by heavy coloured glasses and the hands shielded from the intense heat. From ten to two or three hun-

HEATING IRON IN A PAIL OF WATER.

dred ampères may be used in the welding arc, according to the volume of heat necessary for the work. Regulation is effected by means of a variable resistance, in series with the arc.

The electrolytic heating method, or so-called water pail forge, has also been previously described in this magazine. Any object to be heated is negatively connected and inserted in a solution of common soda or other electrolyte, also containing a large positive lead electrode. Decomposition of the solution by a direct current produces hydrogen gas which surrounds and completely envelopes the negative electrode. The current, passing through the gas, intensely heats it, which consequently heats or even melts that portion of the metal in the solution. The practical apparatus is very simple, consisting of a wooden trough, holding the solution, a positive lead electrode, fastened to the inside, and a metal rest at the top, forming the negative terminal against which the metal is made to bear when inserted in the solution. This method has been quite extensively developed and applied, particularly by Mr. Geo. D. Burton in the United States.

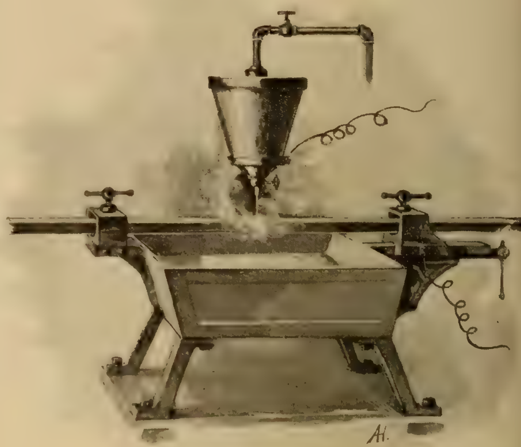
In one of the modifications devised, the process is reversed, that is, the



THE BURTON "LIQUID PROCESS" OF ELECTRIC METAL HEATING.

A, Lead Plate connected with Positive Pole.
B, Metal Bar connected with Negative Pole.

solution is brought to the metal to be heated. The latter is placed on a corrugated support in the trough, also containing the positive electrode. By means of a suitable float and lever the solution is raised until it touches the negatively-connected metal, when the previously described action takes place. Any portion of a bar or rod can be heated by placing it across two movable



HEATING IRON RED HOT WITH A JET OF WATER.

non-conducting supports and raising the solution so that only the section between the supports is brought in contact with the liquid. In another arrangement the solution is sprayed on the metal from a positively connected spout and can be used for welding abutting pieces.

The electrolytic method has also been recently applied to the annealing and tempering of wires. The bath is provided with the usual positive lead electrode and also contains one or more submerged non-conducting pulleys or rollers. The wire is drawn through the bath over the rollers and is surrounded by a continuous incandescent film of hydrogen gas, producing the necessary heating of the wire, which, after leaving the solution, may be drawn through a tempering solution or cooled in any suitable fashion.

Experience has shown that for the best operation of the electrolytic process 200 volts or more are necessary with a varying current which may range from

10 to 100 ampères or more, controlled to a certain extent by the immersed surface of the metal. The density of the solution, usually composed of ordinary soda and borax dissolved in water, also governs the voltage according to its resistance, and if properly proportioned the metal is clean and free from oxide. This method really combines both of the previously described methods, since the incandescent gas envelope is practically an arc. Although not very efficient, it has found numerous applications on account of its simplicity, cheapness and freedom from injurious features. Any ordinary direct current dynamo or supply may be used.

A somewhat similar method in which the heating effect is, however, principally produced by contact resistance, consists of a receptacle containing powdered or broken carbon or charcoal. This forms one terminal and the metal to be heated forms the other. When the latter touches, or is inserted in, the resistance material its resistance and poor contact with the metal generate heat which is conducted to the object and depends on the amount of current used. Either alternating or direct-current of quite large volume and medium voltage are necessary.

Other indirect methods have found special application. One of these, devised by C. Wm. Siemens for melting metals or ores, consists of a graphite containing crucible, which is heated by an arc between it and a suitably placed carbon. The arc may also be direct between the ore and carbon electrode as in the Bernados process.

Heating by radiation and conduction from a high resistance medium through which current is passed and bringing the metal in proximity or contact therewith has also been applied. A machine of this kind, consisting of a carbon tube, heated by the current, is used for heating wires drawn through it. A variety of other odd and, no doubt, interesting electric metal heating processes could be described, but as these have found but very little, if any, practical application it is unnecessary to consider them here.

Generally, electric metal heating and working may be confined to two methods,—generating heat within the metal by passing a current directly through it; or, producing heat in an external medium and heating by conduction or radiation. Each method has its advantages for specific applications. As a whole, electric methods, as compared with others, certainly possess numerous advantages. Rapid or slow heat is simply a matter of capacity of apparatus and current strength; flexibility, space occupied and economy are apparent; the labor required is less, and the cost of fuel is also generally lower than heating by forge or furnace fires, depending, however, on the methods of working and producing the electrical energy.

ENERGY ABSORBED IN ELECTRIC WELDING.—PROF. THOMSON'S PROCESS.

IRON AND STEEL.					BRASS.					COPPER.				
Area in □"	Watts in Primy. of Welders.	Time in ".	H. P. applied to Dynamos.	Foot lbs. unit 1000.	Area in □"	Watts in Primy. of Welders.	Time in ".	H. P. applied to Dynamos.	Foot lbs. unit 1000.	Area in □"	Watts in Primy. of Welders.	Time in ".	H. P applied to Dynamos.	Foot lbs. unit 1000.
0.5	8550	33	14.4	260	.25	7500	17	12.6	117	.125	6000	8	10.	44
1.	16700	45	28.0	692	.5	13500	22	22.6	281	.25	14000	11	23.4	142
1.5	23500	55	39.4	1191	.75	19000	29	31.8	508	.375	19000	13	31.8	227
2.	29000	65	48.6	1738	1.	25000	33	42.0	760	.5	25000	16	42.	369
2.5	34000	70	57.0	2194	1.25	31000	38	52.0	1087	.625	31000	18	51.9	513
3.	39000	78	65.4	2804	1 5	36000	42	60.3	1390	.75	36500	21	61.2	706
3.5	44000	85	73.7	3447	1.75	40000	45	67.0	1659	875	43000	22	72.9	872
4.	50000	90	83.8	4148	2.	44000	48	73.7	1947	1.	49000	23	82.1	1039

AMERICAN VS. EUROPEAN SHOP PRACTICE.

By Robert Grimshaw.

"O wad some power the giftie gie us,
To see oursels as others see us!
It wad frae monie a blunder free us,
And foolish notion."
—*Burns.*

IN the long-agoes, when a patient teacher endeavoured to train my impatient fist to trace calligraphic characters in a copy-book, one of the most tiresome and oft-repeated lines was the alliterative, "many men of many minds." Observation and experience in many lands have confirmed the statement, and in applied mechanics it is none the less true than in a great many other matters.

The mechanic in the Land of the Rising Sun saws from him and planes towards him; puts the roof on his house-frame before attempting to do any ground-floor carpentry; and in many ways does just the opposite from his near-by antipodean fellow-craftsman. We laugh at him, he smiles at us and, by the way, does much better work. But we need not go so far away to seek diversity of practice.

No one here ever sees, as one can see in Germany, a locksmith take a bar of iron and from it make every part of a lock,—case, heart, bolt, tumblers, wards, and springs, and from the same bar forge and file a key which will fit that lock until the crack of doom and will fit no other lock on this footstool. American locksmiths could not do it if they would. As against that, they would not if they could.

Circumstances have conspired to make European craftsmen the better hand workers and those in America the better head workers. But each may learn from the other. To point out some of this in the pages of CASSIER'S MAGAZINE is my privilege and pleasant task. I wish most earnestly to impress on my readers on both sides of the Atlantic that these remarks imply no general superiority of Americans over others, or *vice versâ*. I wish to present merely an analysis and study, as the comparative biologist would dissect and compare animals of kindred species on the two hemispheres, and point out the conditions which have been produced, and those which have been produced by the varying results.

In many cases, as, for instance, those calling for the use of cast iron, American methods would perhaps be of little service, American proportions, certainly, of no use, for imitation with European cast iron and by European pattern-makers, moulders, and founders.

It must be premised that the average American workman, especially if native-born, or, at least brought up in America, is not so "handy" as his fellow-workman of European shop-training. One direct cause of this is the lack of apprenticeship at present prevailing in the United States, and caused very largely by interference of the labour-unions with the employers, limiting the proportion of apprentices to journeymen, so that a skilled workman or an employer is often unable to have his son taught his own trade, even, under existing conditions of instruction and work.

But even were there no such interference, there is but little, and perhaps could be but little, proper general instruction of the young in handicraft, or even in general machine-craft. The days of the good "all-around" mechanic are numbered, partly because there is little or no demand for his skill and labour, and partly because there are few or no

facilities for either instruction or practice in general handicraft.

The necessity for labour-saving has given rise to the American system of making in quantity, not only such things as watches and sewing-machines, but even larger machines, such as power pumps, stationary steam-engines, locomotives, etc.; each part being made separately and by different workmen, to exact standard dimensions, and all being assembled by others.

This calls for expert machine-tenders and assemblers, rather than for skilled general mechanics. Experience sharpens their wits and quickens their output. Competition calls for improved machines and systems, and a still larger scale of working and further subdivision of labour, giving rise not only to mere "piece-work" as opposed to days'-labour as a basis of payment, but to what is known as the "contract system," in which a superior workman in a shop takes a contract to furnish a certain number of pieces of stated dimensions and finish, from raw or semi-raw material also of stated conditions of quality of material and of dimensions and finish, the contractor using his employers' shop, tools, etc., and paying his workmen, if he employs any under him, either by the day, by the finished piece, or by the operation on a partly-finished piece, as best suits him—this, usually, however, being piece-work.

It is for the contract-workman to call for, or even devise, special tools or machines. In the construction of a complicated machine there may be employed several such contract-workmen, some of whom may have workmen under them. A part of the entire work may be done by the proprietors' shop-hands direct, and the rest by contractors; or all may be provided by various contractors. In all cases there is a rigid standard and system of inspection as to dimensions, forms and finish, and stated times, places and conditions of delivery.

In the New York shops of one firm which not only is the largest manufacturer of printing-presses in the world but also makes large quantities of ordinary and "inserted-tooth" circular saws, and other special articles, some of the work is done by gangs of five,—as two men and three boys, or three men and two boys,—who are paid as a "crew" or gang. Each member has to perform special duties which are formulated by the crew itself, and receives certain pay per piece made by the crew as a unit; and each one sees to it that the other four do full work and good work. I have never seen this system in Europe.

Where days' work is the rule, it is usually employed, in the United States, with reference to the best division of labour, each man performing all the operations on a piece, or one operation on all of one or more kinds of pieces, so that the American workman usually becomes an expert planer, or slotter, or miller, and often he tends several machines of one class, all performing the same operation on similar pieces.

It will easily be seen that such a condition of affairs not only does not tend to the development of skill in handiwork, but utterly destroys it by atrophy; also that such a condition tends to intensify itself. Its influence on skill in handicraft may be compared to that of the cutting down of the forests in a country, where such destruction at once diminishes the rainfall, and the scarcity or absence of rain prevents the growth of new forests to replace the old. So in this case, scarcity of labour called for skill in machine-work and the invention of a new system to economise and replace handwork; and there being no fostering influences, handwork, like the forests, must remain a thing of the past.

As an instance of the advantage of the "special" system of working, as against the "general" work, I may cite a case in the United States where boilers were sold in Pittsburgh against competition with a Pittsburgh firm of boiler-plate rollers, and boiler-makers, by an establishment in Bridgeport, which bought the iron of the Pittsburgh rolling-mill and boiler-shop, through the latter's Boston agent, who, of course, made a profit, or added to its cost, by salary and office expenses, had it shipped from Pittsburgh, made it up

by machinery and shipped it back to Pittsburgh more cheaply than the same boilers could be made and delivered by the makers of the iron, in their own city. The side-sheets were cut, planed, curved, punched, and riveted by machinery, and the heads flanged hydraulically at one operation, and punched and riveted by the same means.

While some of the largest European establishments, say those employing 5000 men and upwards, have plate-bending and hydraulic head-flanging machines for their own use, and many more have hydraulic and steam riveters, both fixed and portable, I do not find these machines in shops employing as few men as in the United States, nor in shops of the same amount of annual output. American shops produce more boilers per workman than European do, and more per year per square foot of floor-space.

On the other hand, long before Americans commenced drop-forging locomotive-driver centres and spokes from steel plate, European builders were squeezing out one-sixth sections of wrought-iron driving-wheels, and welding them together by pressure in dies, and were squeezing out entire car-wheels and truck-wheels, ready for the tires. Americans are not likely to perform this latter operation, because they do not use wrought-iron car-wheels.

A noteworthy peculiarity of American manufacturing and machine-shop practice is the employment of castings where Europeans would use forgings, and, where castings are inadmissible, of die forgings, made either by the drop or by the hydraulic system, instead of open forging. Average American wrought iron being somewhat inferior, and average American cast iron greatly superior to that of European make, and casting being so much cheaper than forging and calling for less skilled labour, which might, in fact, not be obtainable, castings have with Americans largely taken the place of forgings, even for complicated designs and where tensile strength is called for. This has led to scientific designing and skill in moulding and casting, which have, further, permitted and encouraged the use of castings, and similarly discouraged skill in open forging.

The use of malleable iron in especial, when many pieces alike, but of irregular outline, are to be made, has received a wonderful development, and not only such parts as rocker-arms, but even complicated pieces, are so made. True, they may get somewhat twisted in annealing ; but they are easily set right by well-directed shaping, and even if ten per cent. were irretrievably spoiled, there would be a great saving over open forging.

The selection of cast iron over wrought iron is not dependent upon the ability of the mechanic to procure or to handle it, but often depends on the inherent quality of the surface-layers of the metal for such purposes, say for gear-wheels, as call for compressive strength and resistance to abrasion ; and here also comes in the advantage of accurately-moulded cast-iron gear-wheels, the teeth of which, preserving the slightly silicious skin and the slightly-chilled outer layer due to pouring in cold sand, resist abrasion, while possessing sufficient internal strength to stand the bending, and sometimes slightly-twisting, stresses produced by meshing while transmitting power. Casting the teeth too large and the spaces too small, and cleaning out with milling-cutters, often considerably lessens the value of the wheels for such purposes as call for severe wear while imperfectly lubricated, and even while subjected to the action of grit.

The employment of metal patterns instead of wood, and of hard wood instead of soft, where the manufacture of cast pieces is continuous, cheapens and improves the product ; while, where the articles are of small size and made in great quantities, several of these metal patterns fastened together are employed and moulded at once. This often calls for moulding-machines, usually operated by foot-power, although, in some cases, by belt, and even by hydraulic pressure.

In small gear-wheel moulding, the

moulding-machine, by its sharp print and straight withdrawal, gives more accurately-shaped and spaced teeth than hand-moulding. For large wheels the use of the radial arm, bearing a segment of two or three teeth which are successively imprinted in the sand, at a circumferential distance equal to one tooth, determined accurately by an index-plate, enables rapid and cheap moulding of better wheels than are secured by whole patterns. It also saves the cost of a separate entire pattern, which might not be required again for years, and of its storage and insurance, enabling prompt delivery of a job (of especial advantage in case of a break-down), and permits the founder either to suit the whims of his customer as to tooth-outline, or to give him a scientifically-correct form of tooth at a cheaper rate than where an entire set of 100 or more must be cut separately and fastened in place on the rim.

The manufacture of cores in quantity has assumed quite respectable proportions in the United States. Plain cylinders of various standard diameters and of considerable length are made and stored, and suitable lengths are cut off as desired. Cores of complicated outline are made by the dozen, 100, or 1000, in the core moulding-machine, and are kept in stock.

I know of but two European establishments of any size that keep standard cores in stock; and the attempt to sell a German core-moulding machine met with signal failure, partly because the machine was rather clumsier than it might have been made; partly because the system of keeping cores in stock (which should have preceded the attempted introduction of the machine), has not yet been introduced and in fact not even much spoken of; and partly, also, because continental Europeans do not make things hundred-wise, and do not cast so much as Americans do. This machine remained a year in Brussels, untried; but I may say in defense of the Belgians, who are enterprising mechanics, that this was principally on account of the lack of personal representation right on the ground.

Die-forging is especially adapted to the manufacture of pieces which must be alike, and the range of such work extends from such thin light pieces as sewing-machine shuttles to such massive members as eye-bars of 18 inches face and 3 inches thickness, for iron truss-bridges, the first being "dropped" at one blow and finished up by subsequent operations, and the latter made in two "squeezes" with a hydraulic press, so accurately as to require but slight reaming in the pin-hole.

With Americans the use of drop-forgings is well understood and practiced. In Europe, except in gun work, it is far less usual. Europe is a far better file-market, per thousand of industrial population, than America, and while some of the more progressive establishments have adopted the suggestion, quaintly put by a leading American emery-wheel making concern, "Why not run your files by steam?" the fact remains that the file is to-day the principal shaping-instrument for small work on the continent of Europe.

The "template" and the "jig" which hold high rank in the American mechanic's working outfit, are less frequently met with on the continent of Europe. In America the steam-engine builder sends out his engine with a board templet to which the foundations may be laid, of proper plan and dimensions, with the holding-down bolts properly placed, ready for the engine to be held by them; and this is often, although not nearly so often as in America, done in Europe.

In America, too, far more generally than on the trans-Atlantic continent, templets and their congeners have figured in many of the operations of making and assembling the parts. I may instance, for example, a small engine connecting-rod, having no adjustment, in which, instead of making the two holes with their axes parallel and at the desired distance apart, and then bushing these with brass or with babbit-metal, and boring the bushings so that

the newly-made holes shall also have axes parallel and at the required distance apart, the rods (which are steel castings with the holes cored therein) are placed on a jig which has two accurately-turned pins representing the future crosshead-pin and crank-pin, and the babbit poured in the holes around those, leaving the bushing-holes parallel, accurately sized and spaced, and of proper finish.

An excellent example of what might be known as a "Yankee trick" in the manufacture in great quantities of cheap articles of workmanship may be seen in certain brass clock-wheels consisting of a spur-wheel, with a lantern-wheel attached, which, in more expensive clocks, would have steel pinions with the teeth properly cut out and the axles turned down small at the ends, and hardened, for journals. In the cheap clocks the axles and the journals are made by taking straight lengths of hard steel wire, duly placing them in a mould, like cores, with the wheel around them, and then pouring in type-metal, to constitute the thick part of the axles and the flanges of the lantern and to hold all the parts firmly together in the proper relative positions as regards perpendicularity, parallelism and centrality.

As to the spur-wheels themselves, which would in many clocks, be of cast brass with the teeth duly cut, one by one, by machine, or even by hand, and the arms filed out to shape, they are in these, as indeed in many comparatively expensive movements, simply stamped out of sheet brass,—hub, arms, rim and teeth,—and such is the accuracy of the punch and the die that the teeth have proper epicycloidal outline and are ready to mesh with those of the mating wheel, without any finishing operations.

Small bells, such as are used for clocks, electric signals, etc., are now made in America by pressing or stamping them out of sheet brass with the hole in the top, and need be finished but little, instead of being cast, and turned out smooth, at least outside and on the rim, as is the usual European method.

The small steel balls, used by hundreds of thousands for bicycle bearings, are now very largely made by rolling, and the same process is successfully employed for conical and other pieces symmetrical about one axis.

In the matter of the utilisation of waste and scraps, American manufacturers have much to learn ; and here they cannot hold a candle to their trans-Atlantic competitors. The scrap-heap still absorbs too large a percentage of the profits, or prevents any profit-making ; and by "scrap" I mean not merely defective or used-up pieces, but those which are cut off bodily in manufacturing other pieces. Occasionally we find manufacturers, such as the needle-maker who makes good black steel pins out of defective needles, and the wood-worker who works up small blocks and sticks of hardwood, which would otherwise be burned, into curtain-rings and poles ; but the proportion is still far too small. On the other hand, there is still made much "shoddy," in which are used materials which should be thrown away or differently used. In fact, it would seem that carpet-makers, for example, can spin and weave every material except sand.

A good example of an ingenious and simple method of producing an article cheaply in quantities is that employed by the Nuremberg toy-makers for making small wooden camels and other animals for "Noah's arks." A ring is turned of soft wood, with its axis parallel with the grain, and the rim having such a cross-section that when it is divided by radial cuts at proper distances apart, it will be separated into pieces having the desired profile and requiring but little else save rounding the sharp edges of the backs and bellies and cutting the spaces between the right and the left legs. Animals like horses and camels, which have comparatively large haunches, are made with their heads towards the axis of the ring ; the lion and the American bison, with their large heads, are made "the other way to." The unknown originator of this process showed therein a high order of genius, although prob-

ably he had few or no opportunities for its development or its exhibition.

But he stopped there. While all the camels cut from a ring are of exactly the same lengthwise vertical section, each ring is turned "by eye" on a foot-lathe, so that the camels of Tuesday are differently humped and the lions of Tuesday differently maned, from those of Monday's output. These toys are made in huts throughout the woods, or in rooms up in back streets, and are collected by agents or brought to the latter by their makers. Labour there is cheap and scattered. In America there would be a "former" made to rip out camel-sections and lion-sections by the thousand, and the workmen would probably split them up and shape them at the factory where the rings were made; or they would receive so many dozen or hundred rings, to be taken home and there worked up into wonders of natural history, at so much per hundred for the workmanship only, just as coats and trousers are cut at American factories and "made up" at the workpeople's homes.

As an instance of the desirability of judgment in the choice of operations to produce a given result or piece, I may mention tenoning. This may be done (1) by rotating cutters with axes parallel to the stick, the latter being moved in a plane parallel to that of the face of the desired tenon; (2) by rotating cutters with axes at right angles to the stick and to the plane of motion of the latter; or (3) by saws, one of which lies in the plane of the face to be left, and the other in the plane of the tenon-shoulder.

It will be seen that either of the first two systems involves the expenditure of more power than the third, because there are so many more faces to be severed, and it is slower; but the rotary cutters leave the faces of the work finished. The saws take less power and are more rapid, but leave rougher surfaces, which, for some purposes, require to be touched up with hand-tools, but for others are sufficiently smooth. The third is evidently for many purposes the best system, unless the shop has no suitable sawing-machinery, and is already fitted with rotary planing-machines which can, with little or no adjustment, be made to do tenoning.

I think that saws are more generally used in Europe in proportion to the number of tenoning-machines, than in America; but in the latter country there are more machines per thousand pieces of a given kind turned out, more per thousand workmen, and more pieces of any given kind, per thousand workmen. When, however, it comes to ability of the European workmen to get up a single one of any given tenoned piece without a machine, he will do it in less time and make a more workmanlike job of it, than his American competitor, also without a machine; that is he will go at the piece without hesitation, and make the tenon straighter, squarer, smoother, and more nearly to the exact size desired, if there be any special set of dimensions called for. If the mortise be already made, he will fit it more accurately and in fewer trials, than the American.

It must be remembered that there are two classes of work where machines can never replace hand-work :—(1) The assemblage of manufactured pieces, as in a typewriting-machine, and its congener the erecting of bridges and other large works; and (2) the construction of experimental machines, including those of which not more than one,—or at most very few,—are to be built. Here the skilled hand-workman finds ready employment in America, at remunerative prices. In some lines there is special call for men who can work with either hand equally well, or together at once; and in some branches of industry such "both-handed" men receive quite a notable extra compensation. In America they are far less numerous than in Europe,—not only less numerous per thousand workmen, but fewer per thousand hand-workmen. Conditions there are not so favourable to the development of "both-handedness."

A 50-TON FLOATING DERRICK IN THE HARBOUR OF GENOA.

FLOATING CRANES AND DERRICKS IN THE HARBOUR OF GENOA.

By Chev. L. Luiggi, Engineer-in-Chief of Harbour Works, Italy.

A PORT of primary importance must be provided with suitable appliances for taking off from ships, or putting into them, very heavy weights, such as big marine-boilers, heavy ordnance, whole sets of engines, completely fitted—weights, that may vary from 50 to about 100 tons each. It is very seldom that the necessity arises in Italian harbours, to lift weights superior to 100 or 120 tons.

As a matter of curiosity, simply, might be mentioned the hydraulic cranes of Spezia, and Taranto, in Italy, which are capable of lifting 160 tons, and the cranes at Chatham Dockyard in England, tested at 350 tons. But these cranes, fixed upon the wharves, are made for special military purposes and are not used for the ordinary routine of a commercial harbour. In the latter case, a crane of from 50 to 120 tons lifting power, is more than sufficient for all the wants of the commerce.

Some discussion has been entertained about the preference for fixed cranes on wharves, or for floating cranes. Experience has demonstrated that it is far more preferable to take the crane to the ship, than to take the ship to the crane, so, for ordinary purposes, floating cranes have decidedly the preference.

This, at least, is what experience has demonstrated as most convenient in the case of the traffic in Italian harbours,

where all big cranes are not fixed on the quays, but float on a kind of large pontoon, which is towed here or there by means of tugs. There are no self-propelling floating cranes.

The type most commonly in use is a floating derrick of 50 tons lifting power. The illustration on the opposite page will give a fair idea of these appliances as used in Genoa for setting concrete blocks at the breakwaters, or removing heavy blocks of stone, or lifting heavy boilers, or pieces of machinery out of ships. This type of derrick is also adopted in all the principal Italian harbours, such as Leghorn, Naples, Palermo, and Venice.

The pontoon, generally made of timber, has about these dimensions :—

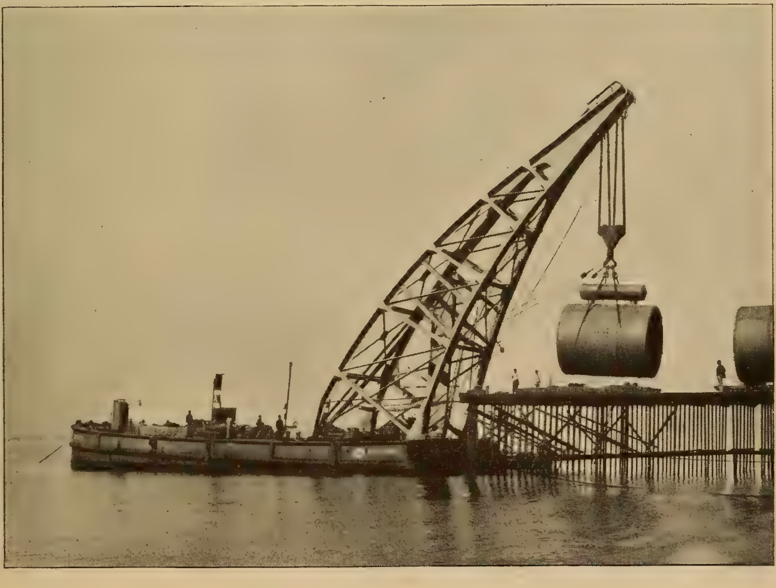
Length of hull	95 feet.
Width	27 "
Depth of hold	10 "
Average draught	5 "

The derrick is formed of two steel tubes, from 65 to 70 feet long, connected together at the top and rigged with steel ropes. The overhang of the jib is about 20 feet and the average lifting power is about 50 tons. The lifting gear is put in motion by a steam engine of from 20 to 25 H. P., and a complete lift of a 50-ton weight to a height of about 30 feet can be done in about 4 or 5 minutes. The cost of such derricks is, on an average, $20,000 (£4000) each. They are usually offered for hire for from $20 to $30 (£4 to £6) a day of 10 working hours, including crew, wages and engine requisites.

These floating derricks are used especially for loading or unloading heavy blocks of marble, concrete blocks, agricultural engines, etc., but they are not so convenient for putting boilers or engines on board ships, because they have not sufficient overhang. Floating cranes are better adapted to this purpose, although they are more costly. The crane "Polcevera," shown on this page and the next one, is a very good specimen of this class of machinery.

Its principal dimensions are :—

Length over all	96 feet.
Width	43 "
Depth of hold	12 "
Height of jib of crane above deck	50 "
Overhang of jib outside deck	30 "
Maximum normal lifting power	120 tons.
Gross tonnage of hull	353 "
Net tonnage	345 "



THE 120-TON FLOATING CRANE "POLCEVERA," UNLOADING HEAVY MARINE BOILERS AT THE PIER OF THE ENGINEERING WORKS OF GIO. ANSALDO & CO., NEAR GENOA.

ANOTHER VIEW OF THE "POLCEVERA."

The hull is built entirely of mild steel, and is strengthened by two longitudinal lattice girders, extending from the stern to half the length of the hull. To these girders is riveted the frame of the crane, and this is also made entirely of mild steel. The deck is of corrugated steel plates, and timber has been used only for outside fenders and internal divisions.

The stability of the crane has been arranged in such a way that with a weight of 120 tons suspended from the hook at the top of its course, and a list of 10 degrees on either side of the axial plane, that is, with the side of the deck beginning to dip into the sea, the crane is still perfectly stable and safe.

At the bow of the hull are arranged several water tanks with a total capacity of 210 tons. They can be filled more or less with water to counterbalance the weight lifted by the crane and thus keep the hull always level. The tanks can be filled by means of a centrifugal steam pump, capable of lifting 200 tons of water in 25 minutes.

In the central part of the hull is the

lifting steam gear which is put in motion by a steam engine of 40 I. H. P. The gearing is arranged in such a way that a weight of 100 tons can be lifted 55 feet in about half an hour. Near the engine room there is space enough for a small repair shop, fitted with lathes, drills and other tools for small repair work. At the stern of the pontoon there are, on both sides, cabins for the crew, and in the centre there is a large open space for ropes, steel cables, chains, etc.

The lifting gear consists of a chain, arranged in four sheaves, passing over a pulley fixed on top of the jib of the crane, and another movable pulley carrying the lifting hook. The chain is guided in its movements by a gear that folds it down in regular layers into a chain pit.

The whole plant was designed and built in Messrs. G. Ansaldo & Co.'s shipbuilding yards at Sestri, near Genoa. It is used for lifting heavy weights from ships, and especially for lifting large boilers, machinery, guns, armour plates, etc., on board steamers or men-of-war.

This is the largest floating crane existing in Italy.

THE AUTOMATIC WEIGHING MACHINE.

By Francis H. Richards.

UNIFORMITY of weights and measures is a recognised commercial necessity. At an early date laws were made, determining the standards of length-measurement, and of weights for use in balances. No laws, however, can fully control the using of the standards, nor standardise the weighing-scales on which the legalised weights are now almost exclusively used in the more important commercial operations. For securing this uniformity of practice, some further resource is clearly required.

The need for such an improvement of practice is emphasised by the gradual lowering of costs and margins of profit, and through the bringing of wider regions within the field of competition, and it has become imperative in some of those larger industries, such as milling, where, in many cases the entire profit is made up of small economies which were formerly neglected.

Two pounds of wheat to a barrel of flour may seem, at first glance, to be a small proportion, but it is one per cent., and, where the annual output is five times the cost of the plant, it represents the interest on the whole investment. In a recent case, a prominent merchant, whose leading competitor used weighing machines, discovered, by having a lot of bags re-weighed, that he had been giving away several tons of fertiliser every day. In another instance, it was similarly figured out that a salt manufacturer of ample estate had, during his extended business career, and by an almost inappreciable overweight, given away a sum greater than his entire fortune. Coming to the use of coal for power, how slight a saving would create a sinking-fund for renewing the plant!

In manufactures generally, it has been observed that a more extended use of machine work, as a substitute for hand work, results in a more uniform product. It is, indeed, now well established that a high degree of uniformity can be attained, within practical limits of cost, only by machine-work, and this carried on automatically. This general rule has been recognised to a limited extent in the art of weighing, automatic mechanisms having long since been introduced for weighing and sort-

ing gold and silver coin. But these machines, being of great refinement of construction, were too delicate and costly for general use.

The search for a practicable automatic weigher, which should be adapted for ordinary commercial work, has extended over a half-century, and enlisted the attention of several hundreds of inventors. Of course, the primary object is to obtain a registration of the material passed through the machine. Practically, this requires the material to be parceled out, and the parcels of portions adjusted to the assumed standard, and then counted. An accurate weighing out of the parcels or loads, followed by a correct counting of them, has, therefore, come to be recognised as the essential requirement.

Until recently, inventors directed their attention almost entirely to the apparatus for receiving and discharging the load, the result being a great number of bucket and valve mechanisms, and an almost unlimited variety of latch and lever arrangements. While some of these earlier constructions were useful, they failed to ensure reliability of operation of the machine as a whole under the exceptional conditions which, in practice, frequently recur, and the weighing machines, therefore, did not possess that peculiar reliability necessary for guaranteeing to the owner that he could settle his accounts on the basis of the mechanical registration. This want of certainty, from the business man's point of view, has been the reason, probably, why the earlier inventions in this line were not generally adopted.

Perfect reliability, however, involves the absence of capacity on the part of the machine to proceed with its work if any of its operations have failed, either in extent of movement or in point of time. If, for instance, the bucket, after discharging the load, has not entirely closed, the supply-valve must be incapable of opening, and *vice versâ*, so that in no case can the material pass through the machine unless this shall operate normally. The recent introduction of an interlocking system of stops between the bucket mechanism and the valve mechanism, thus bridging the gap heretofore separating those normally independent apparatuses, places both mechanisms under one joint control, and marks a new departure in the art. It brings into one organisation the various devices comprised in the machine, and limits the operation of each one by the inoperativeness of any other one, thereby ensuring the stopping of the machine upon the abnormal operation of any part, and before the registration can be falsified.

It seems more than probable that the great success heretofore attained by the so-called platform-scale is due not so much to accuracy of operation as to its thorough practicability as a mechanism for general use in unskilled hands. Similarly, it is not so important, in practice, that the weighing-machine shall have an extreme precision as that it shall maintain a relatively high average, and be constructed on such simple lines that ordinary operatives can understand and care for it. Durability and facility of repair are, of course, relatively speaking, of great importance; but the one cardinal virtue which must characterise the successful automatic weigher, is a good average precision, and an absolutely correct count—an honest count—positively registered.

THE EVOLUTION OF THE HORSELESS CARRIAGE.

By B. F. Spalding.

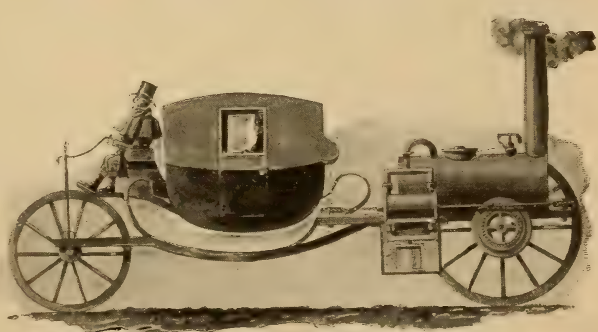
GURNEY'S STEAM CARRIAGE, 1827.

WHEN an eagle, on motionless wings, is sweeping in broadening circles through the sky, one may stand and watch its easy movements and wonder if it senses the exultation of independence that man would feel if he were gifted with equal powers of aerial flight. Who has not, in dreams, been able to ride upon the winds without exertion, and been filled with indescribable delight by the experience? Something of this freedom of motion the skater feels as he skims over the ice.

Judging from present exhibitions of the characteristics of man, his first desire has always been to get somewhere else, anywhere else, away from the place where he happened to be. As he generally had personal belongings to take with him, he cast about for some means of conveyance,—some vehicle, and it has always been his effort to have such vehicles as perfect as circumstances would permit. They were better or worse, as circumstances varied. Change has not invariably been progress, but as the star of empire advanced faster than roads were made, the improvements which had been made in vehicles, in locations where there were good roads, were abandoned where there were no roads, and, also, sank into disuse where the roads remained, but were forsaken by traffic.

In new locations, vehicles improve with conditions, and now, if the right conditions exist, as it is supposed they do, the ideal is imminent, and we are about to have all that imagination can desire in the means of conveyance. This will be a carriage which has, in itself, the power to move swiftly, easily, and noiselessly, and which can be guided with little exertion.

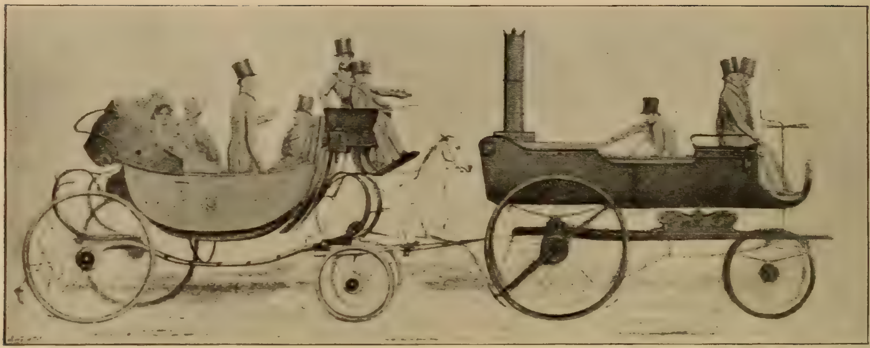
It was proposed to bring together, in this article, some facts bearing upon the subject of locomotion, compiled



SYMINGTON'S STEAM COACH, 1786

simply for the purpose of presenting, in one view, the various stages of development, from crude beginnings to the automotor or motocycle of to-day.

All animals may be regarded as having been subject to the dominion of



FROM AN OLD PRINT.

GURNEY'S STEAM CARRIAGE AS IT APPEARED AT HOUNSLOW, ENGLAND, WITH A BAROUCHE CONTAINING THE DUKE OF WELLINGTON.

man. Each might be looked upon as a special manifestation of force, and one of these forms of manifest force might be more available for use than some other. The patient pull of the ox could be utilised to better advantage than the spring of the lion; the gait of the horse lent itself to man's occasions with less inconvenience than the bound of the tiger or the leap of the kangaroo. With the inanimate forces, the same principles govern the selection in any case of special application. If rocks are to be rent, simply to get them out of the way, dynamite may be employed, but if large blocks are to be disengaged, unbroken, from the ledge, the slower action of lime, or capillary attraction, may be used with better results. Energy appears in so many forms that it is only a matter of adaptation to secure the form most suitable to the purpose for which it is to be employed.

In the case of the propulsion of land vehicles, every form is open, from lightning down. The electric motor is the thunderbolt on tap. It wiredraws the energy that sometimes explodes along the skies, and the lesson to be learned from its taming, is that other, less fierce and fiery explosives may also be caged and made to run in a continuous stream of force—not in tiger leaps, but in a steady gait.

We may explode gunpowder, and we may construct a vessel strong enough to hold the evolved gases, but we cannot retain in association the heat which so magnified them at their birth. Still, we may yet see some way to obtain a steady power, perhaps by means of a steady burning, feeding a little at a time from some of the substances which as yet refuse to serve us, except by sudden impulses.

The genesis of the steam carriage is familiar. It may be said that we owe its first materialisation to Cugnot, who was born in France in 1729, and died in 1804. When he was forty years old he constructed a steam carriage, using steam at high pressure, which carried persons at the rate of two or three miles an hour, in an exhibition which he made of it before Marshall Saxe; but the boiler was so limited in capacity, that after every twelve or fifteen minutes he was obliged to stop to recruit its exhausted energies.

Improving upon this, he built another, but, unfortunately, while whirling through the streets at the reckless speed of three miles an hour, it upset, and, being looked upon with disfavour by the populace, it was condemned, not for any inherent defect, but through prejudice. Fortunately it was preserved, as it deserved to be, and may now be seen at the Conservatoire des Arts, et Metiers at Paris,—an evidence of many things which cannot be gainsaid.

During all the time, from 1760, when Cugnot ran his first self-propelling

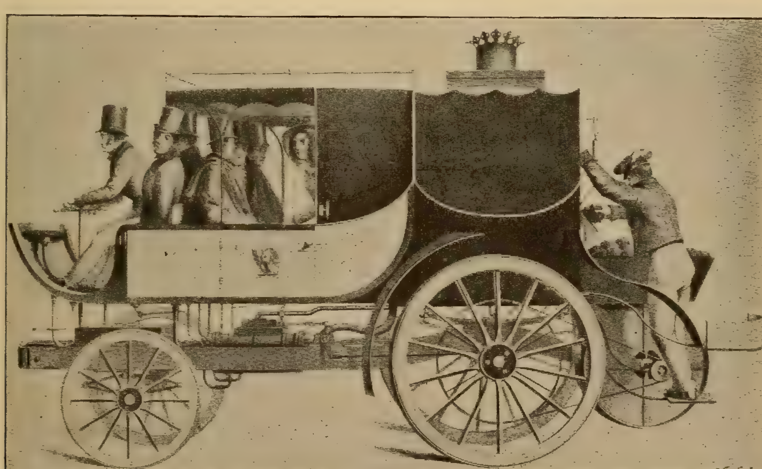
road engine, which, by the way, was named "Antor," until 1802, although many road engines had been constructed, no one had thought of running them on the smooth tramways. It was not until 1802 that a steam-propelled engine ran on rails, and the first to seize this advantage were Trevithick and Vivian. In that year they placed a high pressure non-condensing engine on a Welch tramway, and it is said that it drew a load of ten tons besides its own weight at the rate of five miles an hour.

The Stockton and Darlington Railroad was transporting passengers in 1825, and four years later the Liverpool and Manchester Railroad was opened. In a short time railroad engineering was on a sure footing. It had met with much opposition, and the *Quarterly Review* had seriously rebuked the enthusiasts who had proposed to run at a rate of 18 or 20 miles an hour, sneering even at the name of the new machine, and deprecating its powers. It said :—

"The gross exaggeration of the powers of the 'locomotive steam engine,' or, to speak plain English, the steam carriage, may delude for a time, but must end in the mortification of those concerned. We would as soon expect the people of Woolwich to suffer themselves to be fired off upon one of Congreve's ricochet rockets as trust themselves to the mercy of such a machine, going at such a rate."

These words are not likely to be buried in oblivion, as they would have been if they had been a true prophecy, but they have been kept in pickle to serve to him who dares to cast slurs upon any new project, whether it point sunward or moonward.

Thus were carriages run on the rails, first with horses and then horseless. On the common roads the horseless carriage had more to contend with. After Cugnot's "Antor" was retired, an invention of this kind was patented in London by Moore. In 1772, Oliver Evans, in America, invented a steam-propelled carriage, and in 1786 he was granted the exclusive right by the State of Maryland for the use of a steam carriage designed by him. Murdoch tried his hand at it in 1784, and Symington made one in 1786. Thomas Allen, of London, proposed a plan in 1789. Griffith, in 1821, made a vehicle which carried the engine on two driving wheels. The boilers consisted of tiers of water-tubes, arranged in the fire-box; the upper rows were filled with steam, and as these were exposed to the heat of the furnace, the effect of superheating was produced. But the machine was



SQUIRE AND MACERONI'S STEAM CARRIAGE, LONDON AND BRUSSELS, 1833.

not a success as a self-moving carriage, and two other makers, Burstall and Hill, who constructed a somewhat similar carriage, with the difference that the engine and boiler were supported by the hind wheels, to which they communicated motion, did not meet with much greater success.

Between the years of 1824 and 1830 several road engines were constructed and successfully operated by James, of Birmingham, although they do not appear to have been designed as private conveyances, but for public use. This was a mistake, for they were thus brought into competition with the railroads. They failed to meet the wants of the public. Gordon's device, in 1824, had propelling feet. Gurney's first machine, in 1825, was similarly provided. In the improvement upon this, which he made in 1827, he discarded the feet, and in 1829 he made a notable journey from London to Bath, at the rate of 15 miles an hour.

It is said that the feature of his steam carriage which was most noteworthy was the principle of the high-pressure steam jet, which, when adopted by Stephenson, increased the speed of the "Rocket" from 12 to 29 miles an hour. Some forms of his construction were used to draw other vehicles, like the steam horse or steam bogie carriage of De Dion, Bouton & Co., exhibited at the *Petit Journal* contest in Paris in 1894, and at an exhibition in England, at Tunbridge Wells, last October. A print is extant which shows one of these engines drawing a barouche containing the Duke of Wellington. Maceroni and Squire made a steam coach for use on common roads which was successfully tried in 1833 in London and Brussels. The illustration on the preceding page shows it to be a very neat and common-sense affair.

In 1829 the Liverpool and Manchester railroad was completed, and a prize of £500 was offered for the best locomotive. There had been, from the time of Cugnot, difficulty in raising enough steam, and this was overcome by Marc Seguin, a Frenchman, in 1827, by the use of multi-tubular boilers. Stephenson adopted such a boiler at the suggestion of Henry Booth, secretary of the railway company, and used the steam jet, which was probably first devised by Trevethick. With all these improvements on the "Rocket," he successfully competed with the "Sanspareil," by Timothy Hackworth, the "Novelty," by Braithwaite & Ericsson, and the "Perseverance," by Burstall. He ran at the rate of 24⅓ miles an hour, and on September 15, 1829, the day the road was opened, an engine ran at the rate of 36 miles an hour.

About this time Hancock ran carriages for hire near London. These were mounted on three wheels and were driven by a pair of oscillating engines. They made journeys about London of 128 miles a day. That was more than 60 years ago, and would still be considered a good performance.

Since 1830 the railroads have demonstrated their capacity to transport passengers and freight with safety, speed and regularity. They can now use the argument in their favour which was once used against them and in favour of the canals. It was urged that the Liverpool and Manchester Railway should not be granted right of way, because it was to pass through a district where there were two or three canals, and hence, "there were already sufficient facilities for transportation in the district."

There have been many fugitive and isolated, but, until within a few years, no determined efforts since 1833 to construct carriages for general use which had within themselves the power of propulsion. The same reasons operated against them that hindered, for centuries, the common use of any wheeled conveyances in many countries. Egypt had both chariots and wagons in the days of Joseph, 1700 B.C. The Romans constructed the Appian way, 331 B.C., and other good roads. They were famous for them, as we all know, and carriages were much in use. A thousand carriages were part of Nero's retinue.

It was many years before the roads in

other parts of Europe were good enough to allow the use of wheeled vehicles. The mode of traveling was on horseback. In 1550, it is said, there were but three carriages in Paris; one of these belonged to the queen, one to the king's mistress, and one to a nobleman too obese to bestride a horse. The use of coaches was introduced into England in 1580 by the Earl of Arundel. Before that time, Queen Elizabeth had on public occasions ridden behind her chamberlain.

The roads were not fit for wheeled vehicles even a century later, but the desirability of such vehicles drew attention to the utility of good roads and the betterment of the highways, so that within the century following there were 6000 coaches in London. In 1715 there were 800 hackney coaches in the city, and the streets had become passable. In 1703, Prince George of Denmark, visiting England, spent six hours going nine miles on a common road, and a body of men attended on each side of his coach to keep it from upsetting.

The use of any kind of self propelling vehicles on such roads was, of course, out of the question. The first essential to their use is that the resistance to the propeller shall be greater than the resistance to progression. A horse might as well lie down and kick its heels in the air as to try to draw a load up an ice-clad hill when it is smooth-shod. Similar to the slipping of the horse is the moving of a driving wheel when its adhesion to the track is insufficient to move the load. If the revolving wheel has lugs on its surface, and is put to work on a dirt road to propel a load which it fails to move, it will burrow into the ground like a fox.

Some time ago an experiment was tried with locomotive wheels which, instead of being round, were polygonal. The results did not recommend them for adoption, yet on somewhat the same principle, lugs are used on the wheels of traction engines, and prove to be of great utility. The conditions, however, are not the same. The locomotive wheel brings down the flat of one of its numerous sides, and then the corner of one, upon a steel surface, which practically receives no impression, while the wheel of the traction engine rolls upon the ground, into which the lugs sink, practically converting it into a rack. The lugs on the wheel represent the cogs of the pinion which fits into this ground-rack, and the engine must go along, unless the teeth of the rack or pinion give away. In the case of a traction engine, if the first bite the wheels get into the road is not strong enough to impel the machine forward, it is liable to dig in, and stall itself, unless some resistance is thrown to it great enough to enable it to push itself out.

Consider a traction engine that is used to draw ploughs. Ploughs in the ground are a dead load and never acquire momentum. They are really anchors, and the engine pulling them is like a ship dragging her anchors. The size of an anchor is small in proportion to the size of a ship, but the size of a plough is large in proportion to one-fifth of the wheel contact with the ground. If the weight of the engine be not sufficient to press the lugs of the wheels down into the ground and pack it firmly around them, they will scratch it away and dig burrows for themselves, although they have each a width, in some instances, of three feet or more, and a diameter of five feet.

The pneumatic rubber tire has advantages in point of adhesion and traction which are described by Charles B. King, the umpire who went with one of the carriages in the recent much spoken-of *Times-Herald* horseless carriage contest at Chicago, in the United States. He says :—

"It was a day for showing the benefits of the pneumatic tire over the solid rubber tire. We were equipped with the latter, and, from the start, saw its disadvantages. The solid rubber tire acted like a knife and cut through the slush and even into the mud below. The pneumatic tires, on the other hand, presented a slightly flattened surface which enabled the carriages, thus equipped, to ride on the crest, and maintain a speed that was impossible with us."

There have been many devices for making elastic and yielding wheels, but none have been invented, and it is difficult to conceive how any can be made, that will absorb an impression more immediately than a rubber tire, at the very point and instant of impact. It really absorbs shock, takes it and ends it, and it goes no further. Wheels have been made with spring spokes, some with flexible, elastic rims, and some with stiff rims. They are illustrated in the pages of the technical journals from time to time.

"ELECTROBAT, NO. 4," WITH PNEUMATIC TIRES, BUILT BY MESSRS. MORRIS & SALOM, PHILADELPHIA, PA., U. S. A.

If any one is stricken with the illusion that he has designed a new wheel of this kind which must be hailed with delight, and will supersede all others, he will do well to glance over the back numbers of such a journal, and be sure that he does not miss the earliest copies. It is rather pleasant, after he has kept a fine drawing of his invention under lock and key, safe from the prying eyes of the curious, for ten or fifteen years, while he waited for a happy combination of circumstances, before he rolled it out into the world, protected by an iron-clad patent, to find, in turning over the leaves of publications yellowed with age, that as good a picture as his was made of that identical thing fifty years before. It may be that some of these old devices may yet meet with favour, and that their neglect is caused by their having had an untimely birth. Everything has the proper time appointed for its appearance. This is Nature's law, and buds that put forth in the middle of January will die, but if they wait for their proper time they may come to flower, may fill the air with fragrance, and, sometime, develop into fruit.

Velocipedes were, without doubt, an ancient conception in various forms. It is no proof that any known form did not exist because there is no record of it. It was a hundred and thirty years ago that one figured in an incident

which Boswell relates. He says that one evening when Dr. Johnson, who, by the way, prided himself upon a familiarity with science which his friends disliked to have him exploit, was in a particularly good humour, and ready to talk on all subjects, Mr. Ferguson, the self-taught philosopher, told him of a newly invented machine that went without horses; a man, who sat in it, turned a handle, which worked a spring which drove it forward.

"Then, sir," said Johnson, "what is gained is, the man has his choice whether he will move himself alone, or himself and the machine too."

There is apparently so much good sense in this observation, that we may suppose Ferguson was silenced, and Boswell convinced. It is true that if a man had his legs cut off he would have so much the less weight to carry, or if he had longer legs he would have so much more weight to take along with himself.

The velocipede was neglected for so many years because the conditions were not favourable for their existence. When the conditions became such that their advantages could be demonstrated, the rage for them broke out like a fire which has been smothered, but which, upon receiving an accession of air, breaks out into flame.

Although an increase of weight is at all times an additional burden, there may be observed, at any time, instances where weight increases capacity of motion. When the drivers of an engine slip on the track, it is plainly perceived that if they were weighted enough to obtain the necessary friction, they would adhere to the rails and move the train.

The *Times-Herald* contest in America, like that promoted by the London *Engineer*, has stimulated manufacturers to produce something superior to the French types. Notwithstanding the fact that roads in America are uniformly bad, more progress has been made there than in England. This is probably due entirely to the mediæval law regulating the speed of any mechanically propelled carriage to a pace slower than a man can walk, and requiring in addition that some one shall precede the vehicle waving a red flag of warning. If this act is repealed by the present Parliament, as is anticipated, England will, undoubtedly, keep pace with her American cousins and her French neighbours, for, without doubt, the best constructed roads in the world are to be found in Great Britain, and this is one of the most important factors if horseless vehicles are to come into general use.

An experimental wagon recently built in Philadelphia, which competed at the American contest in Chicago last year,

THE CARRIAGE BUILT BY THE HOLTZER-CABOT ELECTRIC CO., OF BOSTON, MASS., U. S. A.

was constructed by Messrs. Morris and Salom, of Philadelphia, and named "Electrobat No. 1." Ordinary heavy wagon wheels, with iron tires, were used, and the weight of the vehicle, including the storage battery, was 4250 pounds, the battery weighing 1600 pounds. The power was applied to the rear wheels.

The front wheels were for steering. The motor weighed 300 pounds. Tests made with this vehicle showed that, when weighted to a total of 5000 pounds, it could be run on good pavements at 10 miles an hour, with an expenditure of energy of not over three and a half horse-power. It weighed 1650 pounds, and was moved by two motors, each of one and a half horse-power. A change was made in the driving and steering arrangements, and the front wheels were fitted with pneumatic tires, and carried the larger portion of the weight. They were driven by the directly-connected motors. The steering was done with the rear wheels. The speed was 20 miles an hour, and there was enough battery capacity to run more than an hour at this rate.

The convenience of handling the storage batteries, in loading and unloading them, is a matter of importance. Messrs. Morris and Salom have fixed upon a certain size to which, in their subsequent manufactures, they propose to adhere, irrespective of the size of the vehicle or the character of the work required and will obtain the variety of requirements needed by changing the number of cells used on the vehicle, and by various methods of grouping them. The type fixed upon is a 50-ampère-hour cell, weighing about 13 pounds complete. They group 12 of these cells together in a box which weighs about 160 pounds. Four of them will propel an ordinary delivery wagon weighing 1000 pounds, 25 or 30 miles. They can be recharged at conveniently situated relay stations, and two men can lift them out and into the carriages, with ease.

Another carriage was entered by Mr. Harold Sturges, and was the only other electrically-propelled vehicle which used solid rubber tires, but the slipping of the wheels was so great that three revolutions would make only the progress due to one revolution. This waste of energy depleted the store in the batteries, until not enough remained to warrant the attempt to make the race. Mr. Sturges remarked :—"With the gasoline motors, it was simply a case of more gasoline, which was provided for them at the relay stations from sleighs that followed them. Both electro-motor vehicles ran without a single accident or breakage as long as their supplies lasted, and were ready the next morning to have made a similar run."

One of the latest and most successful application of electricity for motive power for road carriages is shown on page 549. This carriage was built by the Holtzer-Cabot Electric Company, of Boston, Mass., and has been given many severe trials with satisfactory results. Notwithstanding the considerable weight of the storage battery supplying the current, this carriage is capable of developing a speed of fourteen miles an hour on roads of average condition and ordinary grades, while the steepest grade may be climbed at a slow speed without undue strain on the motor or battery.

Seven passengers may be comfortably seated, and the carriage is under perfect control and may be run at a speed of from two miles an hour upward. It is readily reversed, can be turned in a small space and may be guided by one hand, leaving the other free for the operation of the brake and controlling lever. A 7 horse-power motor drives the carriage by a chain and sprocket gear as shown ; forty cells of battery are used and so connected to the controller as to give various speeds as may be required. The carriage is of the English break type, a design which lends itself readily to the compact disposal of the battery ; two 12 candle-power incandescent lamps are mounted in regulation lanterns and provide a powerful light when needed. This carriage was built to the order of Fiske Warren, Esq., who had the desire to ascertain just what could be done with such vehicles, and he devoted considerable time and money to develop it to its present state.

The adoption of electric motors for street cars has made people acquainted with their merits. If the passenger will observe the movements of the motorman, he may form some idea of what the person will have to do who controls

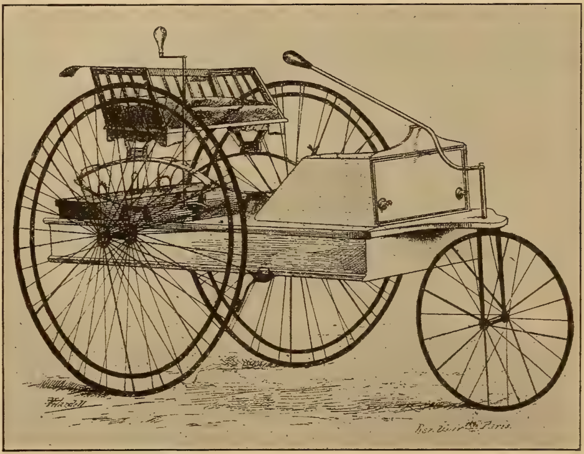
MAX HERTEL'S MOTOCYCLE.

a large motocycle on the highway, and then add the steering, which the tramway does not require. It would appear that the lighter the vehicle can be made the easier it will be to control. In this respect the machine of Max Hertel, illustrated on another page, stands in a favourable light, as in its manufacture he paid particular attention to strength, lightness and compactness, and, to obtain these points, he followed the principles of the bicycle, using seamless steel tubing for the frame, pneumatic tires, tangent spokes and ball bearings wherever applicable. Of the ease with which it is controlled Mr. Hertel says :—

"One lever starts and stops the motor, connects and disconnects it with the vehicle, changes the speed and gear, and sets the brakes instantly, all with a simple forward or backward movement, while the other lever serves to guide the cycle."

A double-cylinder gasoline motor furnishes the power, specially made and adapted to this purpose, transmitting it to the rear wheels by means of friction gearing. The whole weight of this motocycle is only 220 lbs. It carries two persons, and is said to be strong enough to carry eight.

The Carli electrical carriage is a tricycle, constructed at the establishment of Count Joseph Carli, member of the



CARLI'S ELECTRIC TRICYCLE.

ONE OF THE NEW CARRIAGES NEAR THE ARC DE TRIOMPHE, PARIS.

Italian Parliament, at Castelnuovo, in 1894. It weighs 350 lbs. when ready to run. The motor acts directly on the hind wheels, and the battery is capable of running a four or five-hour trip at the rate of ten miles an hour.

Tests of an electric carrage built in Chicago in 1894, by G. K. Cummings, showed that over a level road, at a normal speed of from 10 to 12 miles an hour, the power consumed was from 1¼ to 2 horse-power, and it was estimated that the cost of board for one horse would be greater than the cost of electricity, the carriage to run fifty miles a day. At the published rates, the expense for power would be $10 or £2 a month. Mr. Salom estimates that in Philadelphia, with a population of 1,000,000, the cost of the work done by horses costs not less than $30,000,000 (£6,000,000) a year, and that the same work could be performed by the use of electricity at one-half of this expense. He believes that ordinary delivery wagons can be constructed in America for from $600 to $800 (£120 to £160), and other vehicles in proportion, the prices varying as in ordinary carriage building, pleasure carriages costing from $1200 to $1500 (£240 to £300), and special designs a larger sum.

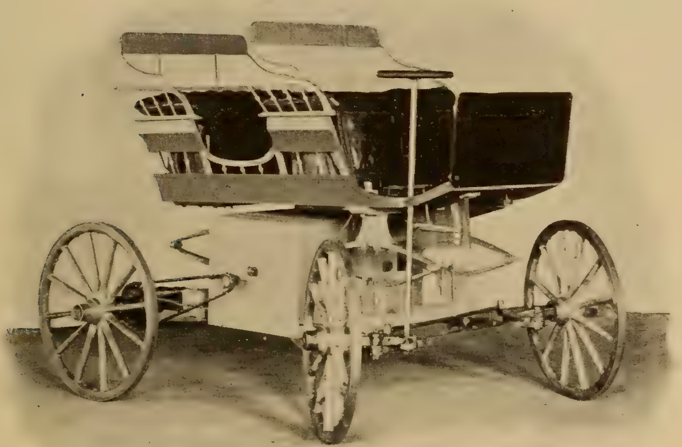
The promoters of the Benz motor figure out the cost of keeping a horse as $339 (about £68) per annum, representing, at 6 per cent., the interest on an investment of $5500 (£1100). To this replies the objector :—"Until all lovers of out-door sport shall be placidly content to be mere motormen the horse will be the favourite." When the motocycle exhibits the swiftness it is capable of, who will be willing to drive a horse till he shows signs of distress? The common sense of pleasure seekers will revolt.

In the vicinity of Paris, in the early part of this decade, movements might have been seen preparatory to the introduction of the automobile. In that

favoured city bright eyes, with eternal vigilance, scan the signs of the times. They saw good roads, good materials, good motors, compressed air, steam, gas and electricity. They saw wealth and liberality standing ready to foster enterprise ; they saw the will to do, the genius to conceive, the skill to execute and the audacity to dare. From all this, it might have been predicted, something was to come.

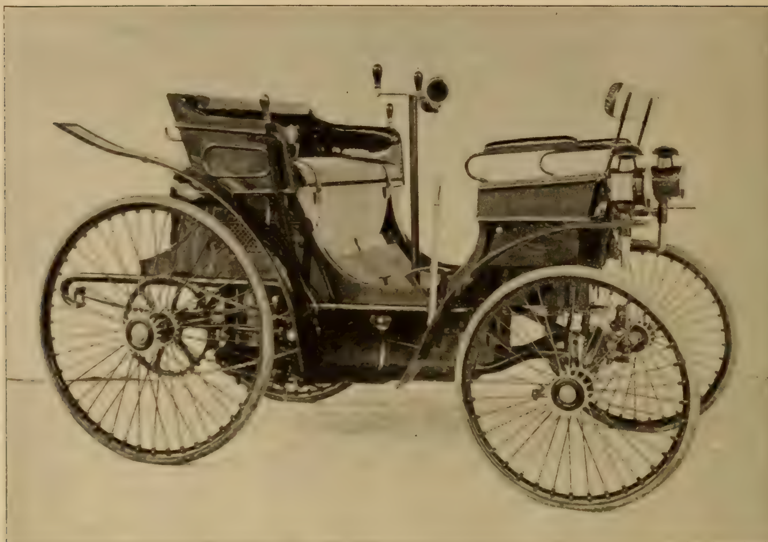
French manufacturers were soon in the field. They straggled at first, but the recent offer of prizes for competition, from the *Petit Journal*, concentrated their attention and gave direction to their aim. After the lists had been kept open for four months, ninety-three entries were made, the number of vehicles being 102. Twenty-three of the vehicles which actually competed were propelled by petroleum ; 12, by steam ; 2, by compressed air ; and 1 by a combination of steam and petroleum. Electricity was not represented. One carriage was entered but did not compete. At the trial, the steam carriage of the Count de Dion, carrying four persons, attained a speed of seventeen miles an hour, and, with the Panhard & Levassor carriage, with a petroleum motor of the Daimler type, carried off the first honours. A visitor to Paris this summer will probably have an opportunity to engage the horseless vehicle by the hour or trip, for a company has been formed for the purpose of putting five hundred out at once.

Many of the French manufacturers now show a line of delivery wagons, and in Paris several of the great stores are contemplating their adoption. The Louvre, one of the largest stores in the world, now has some of these carriages in use for delivering their customers' purchases, and intend, it is stated, to use this type of vehicle entirely. When we consider the immense amount of goods to be delivered in cities and in the country, and think of the number of wagons employed for that purpose, we shall wake up to the magnitude of this branch of the business.



STORAGE BATTERY CARRIAGE, DESIGNED BY GEO. K. CUMMINGS, CHICAGO, ILL., U. S. A.

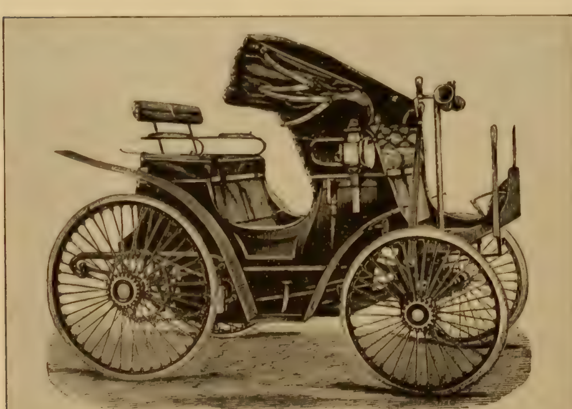
In speaking of the benefit which horseless carriages would be to the community, Sir David Salomon, who has no interest in the subject except as a promoter, said that the circulation of articles of agricultural produce, which they would facilitate, would "bring the distant country districts into immediate touch with the town. They would ful-



THE DESIGN OF MESSRS. PEUGEOT BROS.' SONS, PARIS.

fil the service of light railways ; and to the tradesman and to the professional man the readiness of being able to order out his business cart or carriage at a moment's notice would be of the utmost advantage pecuniarily, as well as time-saving.''

At the agricultural show held at Tunbridge Wells, England, last October, the Mayor of the city, Sir David Salomons, who is chairman of the City of London Electric Lighting Company, organised an exhibition of horseless carriages. Six were shown, among them one built by Panhard & Lavassor, one by Count de Dion and M. Beuton, of Paris, and one by Messrs. Peugeot, of Paris. In the Peugeot carriage a gasoline motor of 3¾ horse-power is used. It is intended to run the carriage at an average speed of 8 miles an hour, which is as fast as safety will allow in town limits. In the country a speed of 15 miles an hour is not dangerous, and this is attainable. The carriage weighs 1450 pounds, and the price is £210, or about $1050. The Messrs. Bloomfield and Garrard, well known in the bicycle trade, constructed an electric road carriage at their factory in Coventry, England. The framework is of seamless steel tubing entirely. The carriage, with batteries, weighs 1000 pounds and is calculated to run at anywhere from three to thirteen miles an hour.



THE DAIMLER MOTOR FIRST PRIZE CARRIAGE IN THE PARIS CONTEST.

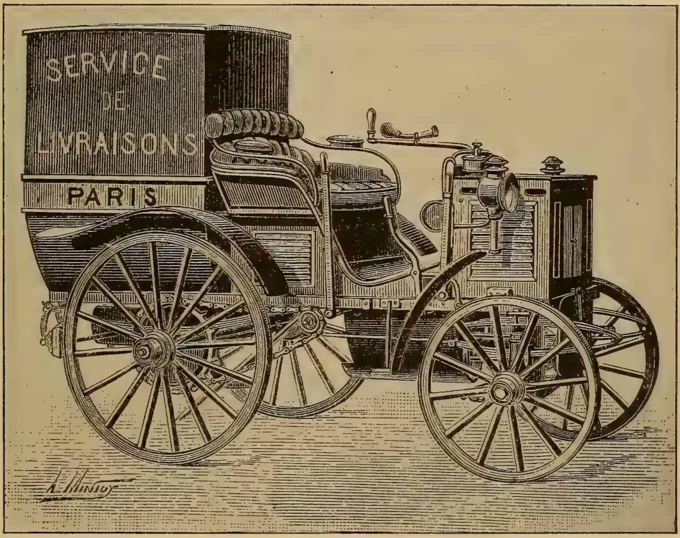
The interest in America centered in the already-mentioned *Times-Herald* contest which was to have been held

on November 2, 1895, but was postponed until November 25. A consolation purse, offered to those who desired to cover a course of about 100 miles on November 2, was won by the H. Mueller Manufacturing Company, of Decatur, Ill.

On November 25 six motocycles appeared to contest for the prize. The roads were covered with slush and snow to the depth of 6 inches, which extraordinary condition had not been anticipated or prepared for by those who had expected to take part in the trial. Motocycles, as such, are not intended to propel themselves on such roads, and it would have been as fair to have laid a course for them over unbroken ground. Such a contest would not decide which was the best vehicle for the uses to which it is designed that they shall be put, and the question as to which is the best for such purposes will not be decided until they meet under better conditions. But, notwithstanding the untoward circumstances, two of the carriages actually did make the journey, and the first prize was awarded to the Duryea motocycle and the second to the Mueller machine.

The Duryea motocycle was designed and constructed by Charles E. Duryea, of Peoria, Ill. This carriage weighs 700 pounds, and is driven by a four-horse power petroleum motor, weighing 120 pounds. The front wheels are 34 inches and the hind wheels 38 inches in diameter. It has a clean-limbed, sensible appearance, and nothing appears to be unnecessarily attached to it. Among the advantages claimed for it are some that the ideal vehicle must possess, such as absence of noise, easy motion, and no disagreeable odour. Mr. Duryea is justly gratified at his success, and claims that the results of the trial settle the question of automobile propulsion. The wagon not only ran over the 54-mile course, but traveled an additional distance, making a total of 70 miles.

The De LaVergne motor drag has three seats and weighs about 1800 pounds. Two Benz motors are used, of 4 horse-power each. It received an award from the judges in the *Times-*



A MERCHANDISE DELIVERY WAGON OF MESSRS. PANHARD & LEVASSOR, PARIS, FRANCE.

Herald contest for counterbalance on the engine. The manufacturers claim that the two cylinders are so balanced that no vibration is noticeable when the vehicle is in motion. Starting and stopping is done by shifting the belts in the smaller carriages, but in the larger vehicles a friction clutch is used which also controls the speed. The motor can be stopped by the motion of a lever, and the motion of the wheels can be reversed without stopping the engine. These carriages are capable, the manufacturers claim, of making a speed of 25 miles an hour. They are provided with a powerful brake.

The Haynes & Apperson motocycle is built in the light of the latest improvements in vehicle construction, as developed in the bicycle business. The steering arrangements are unique and well designed. The motor is a double-cylinder gas engine, the normal speed

THE DURYEA CARRIAGE, WHICH WON THE FIRST PRIZE IN THE TIMES-HERALD CONTEST, AT CHICAGO, 1895. MADE BY THE DURYEA MOTOR WAGON CO., SPRINGFIELD, MASS., U. S. A.

of which is 480 revolutions per minute. It was awarded the highest prize given for preventing vibration by balance of driving engines.

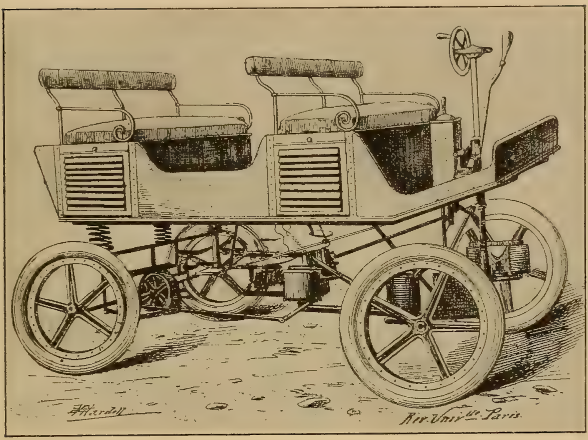
One of the advantages of the motocycle is that when it is not in use it entails no operating expense. All that can be charged to it in its idleness is the interest on the original investment; and when it is used at the rate of fifty miles a day, the expense for running, carrying from two to four persons, either with gas or electricity, would be but about $10 (£2) per month, or five miles a day for $1 (4 sh.) a month. It will not, like an animal, depreciate in value because of the lapse of time. Age does not decrease its value—nothing but use will do that; and if it is made as well as other machinery, it should run for fifty years, with an outlay for repairs of not more than two per cent. per annum on the first cost.

Another advantage is that the carriage does not require continual attention. A man who keeps any living creature, and attends to it himself or by proxy, is under obligations to provide for it, and these limit his freedom.

If he has a horse, he is a slave to his faithful servant; but a motocycle has no such hold. When it has performed its work it may be run into the shed, or into the parlour, after cleaning it. If the owner chooses, he may fit it with a couch and make it a common article of furniture in the house, and, when he pleases, take a trip on it to his neighbour's across the way, twenty-five or fifty miles off.

It is a question whether, in the point of directing the course, the horse, even with his additional intelligence, has really any advantage over the motocycle. The horse will follow the road even in a dark night, but spirited horses, and spiritless horses, are apt to shy at unexpected moments—and the horseless carriage will not shy. It must have a steering apparatus that will act easily when the operator intends to change his course, and which will not deviate until the operator moves it.

In some of the larger vehicles it may be expedient to draw upon the motor for power to assist in steering, but vehicles weighing less than 500 pounds may be guided without assistance by any woman who would trust herself to drive a gentle horse. The preparatory

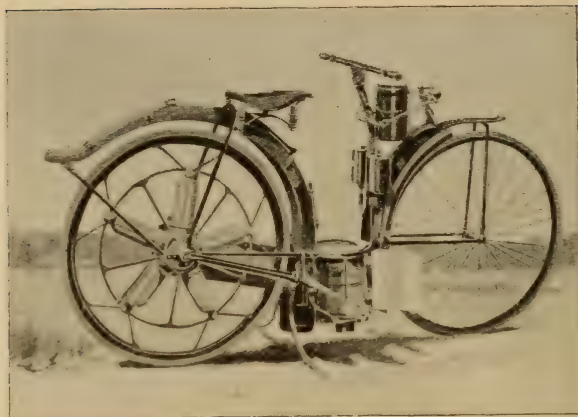


ELECTRIC CARRIAGE OF MESSRS. BLOOMFIELD & GARRARD, COVENTRY, ENGLAND.

arrangements for starting off with these light carriages must be so simple that the schoolgirl can make them herself, get into her carriage, and swiftly glide away to school. A vehicle of this kind will be invaluable to the physician, for it will stand without watching, and never tire, though urged to its greatest speed in the exigencies of life and death.

Whether the use of the fifth wheel

EXPERIMENTAL MOTOR DRAG, BUILT BY THE DE LA VERGNE REFRIGERATING MACHINE CO., NEW YORK.



A PETROLEUM MOTOR BICYCLE.

will be better than the swiveling of the wheels near the hubs, as in several of the machines illustrated, or the arrangement, like in the bicycle, of Max Hertel, is a question which experience will probably decide in various ways, according to the size and purpose of the vehicle. Traction engines have been made on both plans. Thompson's, swiveling near the hub, was strong and satisfactory, but the fifth wheel or the swinging of the full axle survives as the fittest. The motion of the driving wheels, governed or equalised in turning by differential gear, as in Aveling & Porter's traction engine, has, under various forms, been adopted in some of the most ambitious constructions. The self-moving principle has long been appreciated for portable engines and in moving heavy farm machinery.

There are those who believe that the favourite form for pleasure will be a light vehicle, low down, which a man can lift handily, and which will be capable of entering a door of ordinary width, but the advantage of an elevated position will always find favour, and the inconvenience of getting into a high-seated vehicle will be obviated by more convenient steps from the front. The dash-board will not be discarded; it is too valuable as a shield against the wind; but it can be made in a form to be utilised for steps when it is turned down. But if the vehicle be as high as an ordinary carriage, it will not be expedient to make it of narrower tread.

Some carriages will, as now, be driven by the traveler himself, and others will be under the management of persons employed for the purpose, as coachmen and drivers are under the present system. It is yet too early to attempt a classification of motocycles, except in general terms, and under the heads of steam, gas, and electricity,—the classification from the motive power point of view.

There will be no greater dangers to apprehend in case of accidents in the use of any of the horseless carriages than there are from the use of the horse. Accidents, in fact, will be far less common. Let those who have attended to such things recall to mind the men, prominent in the carriage business, who have lost their lives through accidents with horses. Scarcely is there a family, through the country, which has not had some member injured by accident resulting from the use of horses.

A little reflection will convince anyone that the use of motocycles will improve the roads. Gen. Morin, of France, is authority for the statement that the deterioration of common roads, except that which is caused by the weather, is two-thirds due to the wear of horses' feet and one-third due to the

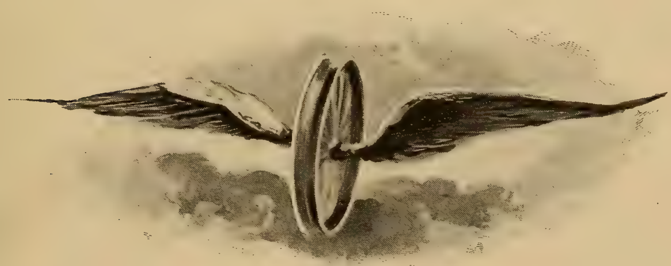
wheels of vehicles. This being the case, if the same amount as usual continue to be laid out upon the roads and the continual damage decrease two-thirds, then the amount spent will go to increased and permanent improvement, and the roads will be "as smooth as a barn floor."

There are many questions to be solved, many difficulties to be surmounted, before the unexceptional vehicle appears. It was a long time before the difficulties of making sewing machines, revolvers, repeating rifles, typewriters, and typesetter, were overcome. Yet, examine them! It is all plain and simple, and not at all marvelous now, and we can hardly imagine how any mechanic could spend years of time, studying over such easy problems. So it will be with motocycles. The mountains of difficulty will sink into molehills, and the ingenuity displayed will be found to take the form of judicious application of ordinary mechanical appliances, approved by the final umpire, the common sense of mankind.

Those who build automobiles must not permit themselves to think that they were born with all the carriage makers' lore inherent in them. A man may be a first-class theoretical and practical mechanic and not be able to make a good vehicle to run on wheels. The perfect carriage, as we know it today, is the aggregate of the years of exhaustive trial and experiment and the improvements on that experience, made by a thousand men of genius.

If the carriage builders bestow upon the new carriage all the art acquired in building the old, and the motocycle men learn the reasons of the conventionalities of the trade and adapt their improvements to them, with reference of the opinions of those who are not prejudiced against innovation, they will both work together in harmony, and with one purpose, and, so united, they will make rapid progress in the development of the inevitable vehicle of the future.

Obviously it is not for the interest of the bicycle manufacturers to push the motocycle to the front where it will in any way hide the bicycle, or threaten its sale by a display of superior desirable qualities. At the same time, it is as evidently for their interest to be prepared to meet any demand which may be made. The most prominent manufacturers are acting upon this policy, and have in leash, ready to let loose when the exigency arises, such excellent devices in motocycles as their valuable experience in bicycles has enabled them to make.



THE DAM OF THE FREYDENBURGH FALLS PULP CO.

POWER FOR A MODERN PAPER PULP MILL.

By Clarence P. Folsom.

IN nearly all lines of manufacturing, competition has become so sharp that the most improved machinery and the reduction in cost of handling the materials of manufacture to a minimum have become important necessities.

The ground wood pulp mills now being erected in many places illustrate this fact as fully as any one class of manufacturing, and one of the best examples of these establishments is found in the one recently put in operation in the United States by the Freydenburgh Falls Pulp Co., of Plattsburgh, N. Y. The site of the mill is about 3½ miles from Plattsburgh, on the Saranac river, where, about 115 years ago, a saw-mill was built by one Freydenburgh, from whom the place receives the name of Freydenburgh Falls.

At the time Mr. Benton Turner, president of the Freydenburgh Falls Pulp Co., began work on the mill, the place was a wilderness, without even a road leading to it, no trace of the old mill being found, except one piece of masonry while the excavations were in progress.

The power used by the mill is obtained from the Saranac river, the dam being a timber structure, 28 feet high at the deepest part of the stream, by 60 feet on the base It is built in crib form, in sections of 10 feet each, which are filled with loose stone. It runs at a right angle with the stream for a distance of 400 feet out from the bank, then a slight angle is made which carries the right hand shore end upstream a little, making another section 300 feet long.

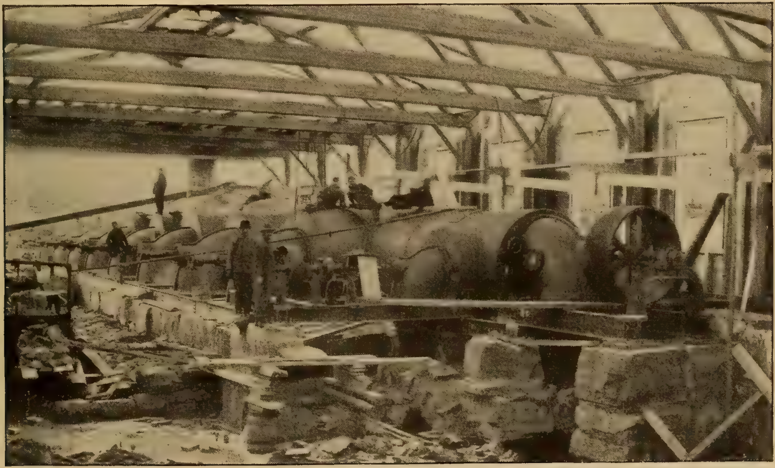
At the left hand end of the dam, looking upstream, are the waste gates, stone forebay and abutment, a view of which is given on the page opposite. This

THE FEEDER PIPE FROM THE DAM TO THE MILL.

shows the forebay walls before the foundations for the wood room were erected. The upstream end of the wood room rests on the lower side of the forebay wall and extends downstream as far as the retaining wall is built against the bank, with the river side on a line with the river side of the forebay.

The grinder and wet machine room is located about 450 feet down stream from the dam, the water for the turbines being carried from the dam to the mill in a steel feeder pipe, made of 5-16ths inch steel plate. The diameter of the pipe is 13 feet 4 inches to a point below where the supply is taken out to furnish power for the wood room, and from there on it is 13 feet in diameter to the inside of the grinder room. The feeder follows the shore and is supported by stone piers, as shown in one of the illustrations on this page.

The building containing the power plant, grinders, screens and wet ma-



SETTING UP THE TURBINES.

THE POWER PLANT AFTER ERECTION.

chines is 330 feet long by 63 feet wide. The grinder room is at the upstream end of the building, the feeder pipe entering this end close to the river side of the building. The power plant consists of eight 33-inch cylinder-gate Victor turbines on horizontal shafts for driving the grinders. Each wheel is in a short flume, connected to the side of the large feeder pipe, which reduces as wheels are taken off. At the lower end of the feeder are a 15-inch and a 30-inch cylinder-gate Victor turbine, the former being used for driving pumps and electric light machinery, and the latter for driving the wet machines and screens.

The centre ot the turbines is 10 feet, 6 inches above the tail water, with a draft tube reaching from the bottom of the quarter-turn into the tail water. The feeder and steel I beams, which carry the quarter-turns and bearings, are supported by the masonry walls which form the wheel pits. Each turbine discharges into a separate pit, which is arched over under the feeder and opens into the river. The turbines operate under a 46-foot head and, including a 24-inch wheel used for driving the wood room, yield a total of 5483 horse-power.

The grinder room is equipped with a traveling hoist over the grinders for

handling the stones. The wet machine room floor is on the same level as that of the grinder room, and is fitted with sixteen screens and eight wet machines. The wood preparing room, which is at the dam, about 450 feet from the grinder room, is equipped with the most improved machinery for hauling the wood from pond and cutting it up, ready for the "barkers," of which there are six of the most improved pattern. From these the wood is carried to the grinders by means of a Jeffrey chain conveyor.

The boiler house is located about midway between the wood preparing room and the grinder room. It contains one boiler 66 inches in diameter and 18 feet long, for heating purposes. Shavings from the "barkers" are used as fuel, being blown directly under the boiler from the "barkers," and all are burned, regardless of the quantity of steam being used.

The first work done on the site of the mill was on June 13, 1894, and the first car of pulp was shipped on March 29, 1895. From that date to Dec. 1, 1895, there were made and sold 4665 tons of dry pulp. When Mr. Turner decided to build a mill, he went into the matter with the intention of having as good a mill as could be made, and now that it is completed, he feels that he has a mill that very few equal and none excel.

The mill and power plant was designed by Mr. A. C. Rice, general superintendent and engineer of The Stilwell-Bierce & Smith-Vaile Co., of Dayton, Ohio, who furnished the entire power plant, including turbines, feeder pipe, head-gate iron, rack frame, water rack, etc.

AN INTERNATIONAL STANDARD OF SCREW THREADS.

By Thomas Mudd, M. Inst. C. E.

JUST fifty-four years ago, Mr. Whitworth (afterward Sir Joseph) read a paper before the British Institution of Civil Engineers entitled, "On an Uniform System of Screw Threads." It consists of a charmingly simple and unostentatious exposition of the process by which he arrived at the table of screw threads that has, for the past half century, been known by his name. One rises from a perusal of his paper with all the more admiration for the man on finding that the process adopted in such a cause was not so much one of scientific experiment or mathematical investigation as of wise compromise amongst existing views on the subject, prompted by a character possessing keen penetration and an unusual degree of human insight.

More copious extracts from Mr. Whitworth's brief paper than would here be admissible would certainly interest the readers of CASSIER'S MAGAZINE, but a few must suffice. After stating that difficulty arises from the variety of threads in use, and that general provision for repairs is thereby expensive, he says :—

"The difficulty of ascertaining the exact pitch of a particular thread, especially when it is not a submultiple of the common inch measure, occasions extreme embarrassment. This evil would

be completely obviated by uniformity of system, the thread becoming constant for a given diameter. The advantage would assume a character of public importance. Public convenience would be promoted in various ways, easy to trace though leading to results perhaps little expected, and the economy of screwing apparatus, however considerable, would become insignificant when compared with the contingent benefit to other interests."

Having thus set forth, briefly, the desirability of uniformity, he proceeds at greater length to show how impossible it is to claim for any particular thread that it can be proved to be better in all respects than any other thread, and that choice in such a matter must necessarily be to a great extent arbitrary. So important, indeed, does he make this point, that about one-half of the paper is devoted to the enforcement of it. Thus he says :—

"It is impossible to deduce a precise rule from mathematical principles, or from any number of experiments. No exact data of any kind can be obtained for calculation, and the problem will be found to be capable only of approximate solution. There are three essential characters belonging to the screw thread, viz., pitch, depth and form. In the selection of the thread, considerable latitude of choice will be found to prevail with reference to all the characters. No definite rule can be given for determining any one of them. The choice must be guided rather by discretion than by calculation."

These statements are at considerable length, and finally summed up as follows :—

"Such being the variety and vagueness of the principles involved in the subject, a corresponding latitude might naturally be expected in their practical application, and, accordingly, we find, instead of that uniformity which is so desirable, a diversity so great as almost to discourage any hope of its removal. The only mode in which this could be attempted with any probability of success would be by a sort of compromise, all parties consenting to adopt a medium for the sake of common advantage. The average pitch and depth of the various threads used by the leading engineers, would thus become the common standard, which would not only have the advantage of conciliating general concurrence, but would, in all probability, be nearer the true standard for practical purposes than any other."

It was thus Sir Joseph announced his suggested method of arriving at a uniform system of thread—not by any abstruse mathematical investigation, not by any lengthened series of mechanical experiments, but by the more direct and simple method of striking an average of the threads then in use by the leading engineers—a method that had, as he says, the advantage of "conciliating general concurrence," because it did not ignore what other engineers had thought and done on the subject, but embraced and included all the practice of his day. Accordingly he says :

"An extensive collection was made of screw-bolts from the principal workshops throughout England, and the average thread was carefully observed for different diameters. The ¼, ½ and 1½ inches were particularly selected, and taken as the fixed points of a scale by which the intermediate sizes were regulated. The scale was afterwards extended to six inches."

In this manner, then, was inaugurated the first successful attempt at uniformity in the practice of a great engineering nation in the matter of screw threads. At a later date, namely, about thirty-one years ago, another great engineering nation, the United States of America, felt the pressure of this subject, and the well-known engineer, Mr. Wm. Sellers, championed the cause. Looking at the matter from a slightly different standpoint as that of Sir Joseph Whitworth, he did not propose the adoption of the Whitworth thread, which had then been twenty years growing into vogue in England, but, without ignoring it, made an independent survey of the subject, and laid his views before the Franklin Institute in April, 1864. A committee of that Institute, including Mr. Sellers,

was formed to consider the subject, and reported in December of the same year.

In the following year a rather voluminous paper was read before the same institute by Mr. Robert Briggs, but, so far as the writer is aware, it did not influence the ultimate issue, which was that the Sellers thread became as widely adopted in the States as the Whitworth was in England.

There are three ways in which the Sellers thread differs from the Whitworth. Firstly, the angle is 60° instead of 55°; secondly, the top and bottom of the threads are square—that is, they are formed by lines parallel with the axis of the bolt, instead of being rounded as in the Whitworth; and thirdly, the pitch of thread of a few sizes of bolts, especially those from 1⅜ inch upwards, is slightly—though only slightly—modified.

It is perhaps on the question of angle of thread that the method of averaging existing practice, adopted by Whitworth, proved least satisfactory in the result, when looked at in the light of what has since occurred elsewhere. He says:

"The mean of the variations of angle in one-inch screws was found to be about 55 degrees. As it is desirable that the angle should be constant, the angle of 55 degrees has been adopted throughout the entire scale."

On this question of angle, the report of the committee of the Franklin Institute states:— "Your committee decided that threads having their sides at an angle to each other must necessarily more nearly fulfill the first condition (strength) than any other form; but what this angle should be must be governed by a variety of considerations, for it is clear that if the two sides start from the same point at the top, the greater the angle contained between them, the greater will be the strength of the bolt; on the other hand, the greater this angle, supposing the apex of the thread to be over the centre of its base, the greater will be the tendency to burst the nut, and the greater the friction between the nut and the bolt; so that, if carried to excess, the bolt would be broken by torsional strain rather than by a strain in the direction of its length.

"If, however, we should make one side of the thread perpendicular to the axis of the bolt, and the other at an angle to the first, we should obtain the greatest amount of strength together with the least frictional resistance, but we should have a thread suitable only for supporting strains in one direction, and constant care would be requisite to cut the thread in the nut in the proper direction to correspond with the bolt.

"We have consequently classed this form as exceptional, and decided that the two sides shall be set at an angle to each other, and form equal angles with the base. The general form of the thread having been determined upon the above considerations, the angles which the sides should bear to each other has been fixed at 60 degrees, not only because this seems to fulfill the conditions of least frictional resistance combined with the greatest strength, but because it is an angle more readily obtained than any other, and it is also in more general use."

In Whitworth's paper the question of the shape of the top and bottom of the thread is not discussed, but the following statement appears: "In calculating the depth, a deduction is to be made for the quantity rounded off, amounting to one-third of the whole depth—that is, one-sixth from the top and one-sixth from the bottom of the thread. Making this deduction, it will be found that the angle of 55 degrees gives for the actual depth rather more than three-fifths, and less than two-thirds of the pitch. The precaution of rounding off is adopted to prevent the injury which the thread of the screw and that of the taps and dies might sustain from accident."

This point is very fully discussed in the report of the Franklin Institute committee, too fully, indeed, to allow of complete quotation, but the following is the summing up:—

"Your committee are of opinion that the introduction of a uniform system would be greatly facilitated by the adoption of such a form of thread as

would enable any intelligent mechanic to construct it without any special tools; or, if any are necessary, that they shall be as few and simple as possible, so that, although the round top and bottom presents some advantages when it is perfectly made, as increased strength to the thread and the best form to the cutting tools, yet we have considered that these are more than compensated by ease of construction, the certainty of fit, and increased wearing surface offered by the flat top and bottom, and therefore recommend its adoption. The amount of flat to be taken off shall be as small as possible, and only sufficient to protect the thread; for this purpose, one-eighth of the pitch would seem to be ample, and this will leave three-fourths of the pitch for bearing surface."

It seems a little strange that neither of these authorities discuss the question of making the bottom of the thread different in form from the top, nor say anything about the detrimental effect on the bolt of a sharply-cut angle at the bottom of the thread. Much might be said in favour of a square top and a round bottom in the thread of the bolt, and the reverse of that in the nut, the taps for the nuts having square top and round bottom like the bolts.

On the question of pitch there is a very close agreement between the Whitworth and Sellers threads. Commencing at ¼ inch diameter, there is no difference, except in the ½ inch diameter, until we get up to 1⅜ inch diameter. Then four or five sizes are slightly finer in the Sellers than in the Whitworth scale, up to 3½ inches diameter, and then four or five sizes, from 4½ inches to 6 inches, are slightly coarser than Whitworth.

Both authorities state that if it were not for the fact that threads are wanted in cast iron, the scale of pitches might very well be finer than that determined upon. It is rarely that screw threads are made in cast iron nowadays, except in the way of stud holes, and these do not run up to the larger diameters of the scale, where in bolts and other fastenings the coarseness of the threads seems increasingly objectionable, the increase of pitch with the increase in diameter less necessary, and the cost of a multiplicity of tackle more and more pronounced.

In the Whitworth scale there are eleven different pitches from 1½ inches to 6 inches, and in the Sellers there are fourteen. It is doubtful whether there need be any at all. Some English engineers have taken this view, despite the argument that threads finer than Whitworth's are difficult to start back, and have adopted the six threads per inch of the 1⅜-inch and 1½-inch bolts in the scale for all higher diameters up to 6-inch diameter.

This gives a good holding thread where there is jar, such as in engine work, but it must be admitted that in the larger diameters, and where the material of rod and nut are of a clinging character, like mild steel, there is difficulty in slacking off after the fastening has been subjected to much stress, as in the nut attaching a piston-rod to a piston.

Enough has been done, however, and over a sufficiently long period, to show that great practical simplification may be effected, with good results, in the direction indicated. Probably some compromise, such as carrying the six threads per inch from 1⅜ inches to 3 inches, five threads to 5 inches, and 4 threads for all larger work, would be found ultimately the best.

On the continent of Europe the confusion of threads appears to have continued up to the present year, despite the fact that France has been many years ahead of the rest of the world in the simplification and unification of standard measures. The French Minister of Marine has now taken a step that will result in uniformity of screw threads in that country on a scale of pitches very nearly approaching the two older scales already discussed, but conforming to metric measure, the form of the thread being precisely that of the Sellers thread, namely, with an angle of 60 degrees and flat top and bottom. This standard will probably soon receive adoption by all European nations using metric measures.

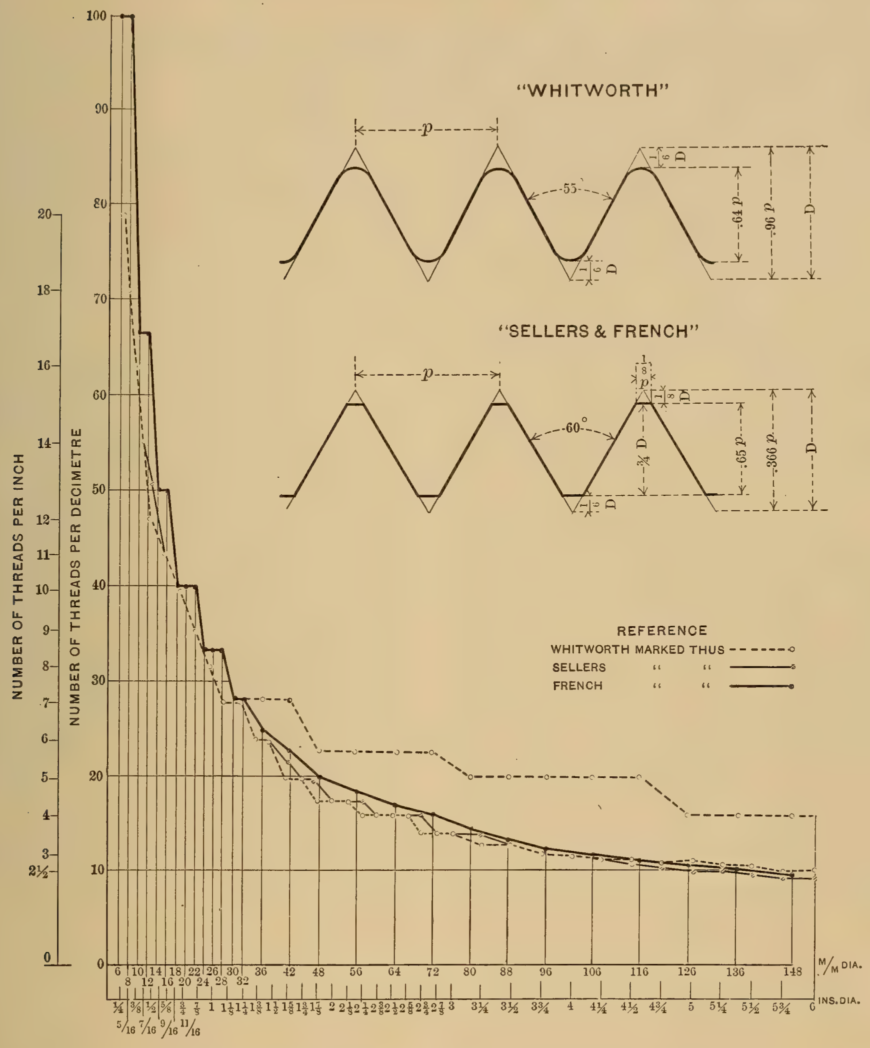


DIAGRAM OF WHITWORTH, SELLERS AND FRENCH SCREW THREADS.

The near approach to each other in point of pitch, of these three standard threads—namely, the Whitworth, the Sellers, and the French standard thread—is best shown by the accompanying diagram, where the line with white circles represents the Whitworth scale of pitches, the shaded circles showing Sellers' variation therefrom, and the full line the French pitches, given in metric measure, and for bolts of metric diameters commonly in use.

When one looks at this diagram in a general way, one is struck by the close similarity of pitch curves, and cannot help bemoaning the fact that they are not absolutely identical. Why should there not be an international standard of screw threads? Why should not the whole engineering world agree to use the same thread? The same arguments that were brought forward in favour of a national thread hold good for an international one. All nations using it would participate in the advantage, and the case is simpler now,

because it is already reduced to a very narrow compass.

The difference between English and metric measures offers a difficulty, so long as the clumsy old English measure lasts. But the fact that both in America and in England the times are becoming ripe for the adoption of the metric system renders the present time especially opportune for the discussion of an international thread. In changing from English to metric measure, some change in screw threads must be made to make them conform to the metric sub-divisions of the unit length. Then why not embrace the opportunity to institute an international standard of threads ?

There is much good sense in the French scale, especially up to 32 mm. diameter, the same pitch being used for two or three adjacent diameters for the purpose of economising tackle. But in the larger diameters, which are little used compared to the smaller ones, this principle appears to have been abandoned, probably with the object of keeping these threads not far away from the pitches of the two older standards.

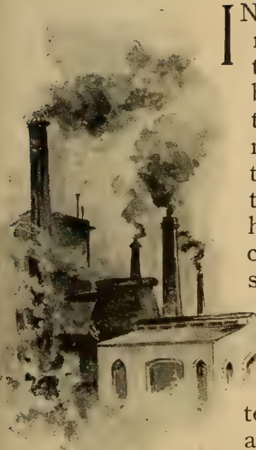
For heavy engine work, however, in which, perhaps, the largest amount of work in these larger diameters is done, these pitches are too coarse for screwing home with ordinary means available, and too prone to slack back by vibration, besides involving unnecessary outlay in tackle. The very diagram itself appears to indicate that as the diameters increase, more and more sizes might be included in one pitch of thread, and the curve follow such a course as the dotted line for diameters over 32 mm. Threads that are satisfactory for engine work would doubtless be found equally satisfactory for bridge and other structural duty.

The primary object of this paper is not to suggest what the international standard thread should be, but to call attention to the desirability of its establishment, in the general interest; to show that with existing practice so near amongst the principal threads in use, there can be little real difficulty in arriving at a general understanding; to point out that now is the time for the discussion of the subject, so that the inevitable change to metric measures may embrace also the change to international uniformity in threads.

If the subject be approached in the spirit that animated Sir Joseph Whitworth, all parties showing a willingness to give way a little for the sake of arriving at a "general concurrence," the establishment of an international system of screw threads will soon become an accomplished fact.

POWER FROM TOWN REFUSE.

By F. W. Brookman.



IN this article I shall deal more particularly with the generation of steam by burning refuse from towns and cities, and refer to a number of tests made to prove that a large quantity of high pressure steam can be so produced. I shall also have something to say as to the effluent gases generated. The experiments and tests mentioned were all made at the Sanitary Manure Works at Rochdale, England.

The present population of that town is about 73,000. The trade is a very mixed one, including woollen and cotton mills, engine and boiler works, carpet factories, dyeing establishments and others, together with many branches of business more or less connected with them. The death rate of Rochdale in 1894 was 16.2 per thousand, and during a number of years it has not averaged more than about 19, but it was not always so, for in 1848 it was 32 per thousand, of which the zymotic (and preventable diseases) death rate was nearly 8 per thousand. The conclusion arrived at was that bad drainage, overcrowding, foul middens and the storing of the refuse in the proximity of dwellings were chiefly responsible for the sad state of affairs.

At that time nightsoil and sewage treatment was neither understood nor practised ; still, it was thought that if the old middens could be abolished and the fæcal matter at the same time kept out of the local streams a very decided advantage would be gained.

With this in view the pail system was initiated and the excretal matters are now concentrated and made into a valuable manure, for which there is a ready sale. The refuse is burned.

In the manufacture of the manure, the refuse supplies all the heat necessary for the evaporation, and also the steam power to turn the whole of the machinery, which latter will take, on an average, 100 indicated horse-power for about 130 hours per week. Besides the refuse so burned, a considerable quantity is consumed in destructors, and it is with these that I shall more particularly deal.

The primary object in putting down these destructor cells was to burn the refuse in the best possible manner, without creating a nuisance with the fumes from the chimney, which meant that complete combustion must take place in the furnace, so as to prevent any unburnt gases, or fumes produced by a distillatory action of the fire on the refuse, from passing to the chimney. This was rather a large order, considering that no separate cremator was to be used ; nevertheless it was successfully carried out, and the destructor cells have given every satisfaction. As additional boilers were required as a stand-by for the manufacturing plant, it was decided to erect them with the destructors.

In a number of towns some steam is generated by burning refuse, but, with few exceptions, the amount of steam thus produced is very small and scarcely enough to give encouragement to those who designed or worked the plant.

In a recent report to a county

borough it was made out that (not counting the few exceptional cases) only 1·5 horse-power per cell was obtained on an average, or, more exactly, one horse-power per ton of refuse burned.

In spite of the low power obtained in the majority of cases where steam is generated by the use of refuse, the Health Committee of Rochdale ordered two large Lancashire boilers, and, with the possibility of electric lighting in the near future, it was decided that these boilers should be built for working at 120 pounds pressure per square inch.

In building the two destructor cells a large combustion chamber, common to both, was provided between them and the boilers, so that the gases could intermingle, and that time should be allowed for the combustion of the gases before they came in contact with the comparatively cold surface of the boiler, noting the fact that if once the organic matter in the fumes were heated sufficiently high, no amount of subsequent cooling down could again make them malodorous. Complete combustion, then, is the first consideration in burning refuse, after which the more heat which can be absorbed, the better, so far as the steam generation is concerned.

For the maximum steam production no doubt the boiler should be brought nearer the grate, or over the top of it, but I contend that by such an arrangement thorough burning of the gases cannot take place, neither can it when the refuse is burned in an ordinary boiler firebox, for in both these cases dense heavy fumes will pass up the chimney each time the fire is charged with fresh refuse. If sufficient space be allowed between the furnace grate and the boiler, and the temperature be maintained at or over 1200 degrees Fahr., complete combustion will take place provided there be oxygen present in sufficient quantity.

It has been proposed several times to complete the combustion of the gases by passing them over or through a second grate, worked by coal or coke, and if very carefully worked, this may succeed, but there will be the risk of black smoke getting away as well as the fumes immediately after the coal grate is freshly fired. There is also a possibility that no more steam will be generated than would be the case with the coal grate alone, burning exactly the same quantity of coal. This would be due to the large amount of cold air admitted at the multitude of doors and feed openings, and which might, with a little carelessness, do more harm than the refuse was doing good, so far as steam raising is concerned.

If this second grate is to act as a cremator it must, moreover, be worked by coal even at light load time. In the combustion chamber furnace, refuse will do the work alone, but if the plant be overloaded at maximum load time in electric lighting, it is best to then use coal say for two to three hours and return to the refuse as quickly as possible afterwards.

The boilers at Rochdale are 30 ft. by 8 ft. and will work, as already stated, up to 120 lbs. pressure per square inch; the grate to each boiler is 9 ft. by 5 ft. It is made by Messrs. Meldrum and is fitted with their steam jet blowers. The plan of the boilers and furnaces is shown on page —. It will be seen from the plan that the boilers and furnaces may be worked in three different ways: No. 1—Both furnaces and both boilers; No. 2—One furnace and both boilers; No. 3—Both furnaces and one boiler.

A number of tests were made early in 1895, mostly with No. 1 method of working. Unscreened refuse was burned and an average pressure of 113 lbs. per square inch was maintained. Every pound of refuse evaporated 1.64 lbs. of water from a feed temperature of 53 degrees Fahr. If calculated from and at 212 degrees Fahr., it comes out 1.97 lbs. (nearly 2 lbs.), even with the boiler so far from the grate as to allow a large combustion chamber between.

Two other tests were made with the view to seeing what could be got out of one boiler with both grates working (No. 3 method), the other boiler standing under full steam and serving for thermal storage at the same time that

it could be put to full work at a moment's notice. The average of the two tests per pound of refuse, the water being evaporated from and at 212 degrees Fahr., comes to 1.73, and I certainly believe that this (taking into consideration the rate at which the boiler was steaming) has never been approached by any boiler worked by refuse.

In this double-boiler arrangement the second boiler, if not required for steam generation, will act as a thermal storage tank, while at any time it can be worked in conjunction with its neighbour so as to get more work done per pound of fuel burned as in the other tests. For instance, the average of the two tests just given was 2 tons 3 hundredweight of refuse burned per hour; in the former tests 1 ton 18 hundredweight was burned, making a difference of 5 hundredweight per hour more refuse burned to do less work in one boiler.

It may be noticed also that in an ordinary destructor, having a 5 foot by 5 foot grate and burning 6 tons per 24 hours, the refuse burned per foot of grate per hour would be 22.4 pounds, or, with 7 tons per 24 hours, 26.1 pounds, whereas in the two last mentioned tests the average quantity burned per foot of grate was 53.8 pounds, showing that double the work (so far as burning alone is concerned) can be done by a forced blast grate than with simply good natural draught.

Tests have shown that from an economical view of the fuel used, the No. 2 method will answer the purpose best, and during the summer, when refuse is at its lowest and the load on the electric lighting station is never heavy, it may be important to be able to work under the most economical conditions, more particularly as the introduction of coal into a destructor station will certainly have a bad effect on the men.

These tests have shown also that from and at 212 degrees Fahr. over 2 pounds of water can be evaporated by the heat generated in burning one pound of unscreened refuse. It may, however, be thought that Rochdale refuse is exceptionally rich in combustible matter, hence the good results; but, as a matter of fact, it is a rare occurrence for the clinker and fine ash to fall below 35 per cent. Low-quality material, with over 50 per cent. clinker, has been successfully burned, evaporating 1.36 pounds of water per pound. The refuse consisted, to a very great extent, of dry, fine ashes, almost like dust.

During the past twelve months considerable trouble has been experienced on the European continent in burning, or trying to burn, low-quality refuse, and I would suggest that the above is an answer as to whether it can be done in a satisfactory manner or not. Here we have a unit of plant consisting of two destructor cells of 45 square feet of grate surface each and two Lancashire boilers 30 feet by 8 feet, and these can be worked with refuse in three different ways, and although the results differ as to economy of fuel, or the quantity of water evaporated per pound of refuse, still, under the circumstances of each case, the results obtained are exceptionally good, and show exactly what really good and substantial, yet simple, appliances, operated by men who know their work, can do.

But we will suppose that there is such a heavy maximum load that the requisite amount of steam cannot be obtained from refuse in any way. We then still have an alternative in that as soon as the load is too heavy for refuse firing, coal can be used for, say, two or three hours of the maximum load time, and, as soon as the peak is passed, we can again fall back upon the refuse.

To make sure that the waste of heat from the coal would not be prohibitive, I made a test with that material as fuel with the result that over 7 pounds of water were evaporated per pound of coal, from and at 212 degrees, or a total of 79,615 lbs. There is no doubt that, under ordinary conditions, an evaporation of over 6 lbs. of water per pound of coal can be obtained after the men have had a little more experience with that fuel. The result, as shown by the test figures, seeing that the grate is a considerable distance from the boiler, cannot but be considered as satisfactory. No doubt somewhat more coal is used

DESTRUCTORS FOR THE ROCHDALE SANITARY WORKS, BUILT BY MESSRS. MELDRUM BROS., MANCHESTER, ENGLAND.

under these conditions than in the best practice with coal-fired boilers, but there are many of the latter which do not come up to the above figures. Another point is that the cheapest kinds of coal can be used for the cells. It must be distinctly understood that I do not recommend this arrangement where coal is the only fuel, as I know well what can be done in good practice with an internally fired boiler.

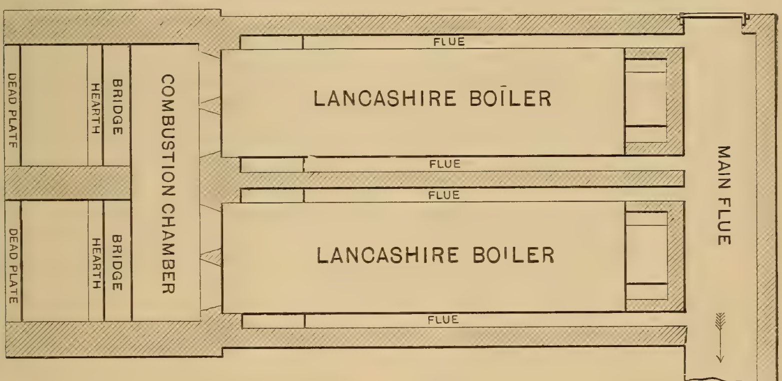
The water evaporated per hour during one test, using coal, with 45 sq. ft. of grate, was over 100 gallons more than that from the refuse in an earlier test with 90 ft. of grate in work, and if this margin is not enough to supply the maximum load, the whole 90 sq. ft. of grate can be used when a much larger quantity of water will be evaporated as a matter of course. I shall assume that 140 lbs. pressure per square inch, with a good feed heater, can be got as easily as 113 lbs. without one, and I shall take the evaporation of the unit of plant as 700 gallons per hour as shown by tests, and the refuse used as 2 tons per hour per unit of plant. Deducting the steam used for the blast we still have over 600 gallons per unit of plant. As some other writers seem to consider that 15 lbs. of steam is ample per horse-power indicated, I will also follow this figure, so that comparisons can be easily made.

The 600 gallons of water will, therefore, represent 400 I. H. P. from one unit of plant, burning 2 tons of refuse per hour, and allowing 15 per cent. of this as frictional loss in the engine, the figures will come out 340 brake H. P., and three such units of plant would give 1020 B. H. P. We will call this, in round figures, 1000.

If we take 420 tons of refuse per week as the available supply of fuel, there will be 60 tons per day, which we will divide as follows :—

5 hours at 6 tons per hour = 30 tons or 1000 B.H.P. per hour.
5 hours at 3 tons per hour = 15 tons or 500 B.H.P. per hour.
14 hours at 1 ton per hour = 14 tons, say 150 B.H.P. per hour.

The remaining ton may be used in banking certain fires. We have thus full load 5 hours, half load 5 hours, and a light load and steam up the remainder of the 24 hours. If thermal storage tanks were used, the refuse could be burned at the rate of 2½ tons per hour all through the 24 hours. This weight of material, however, divided between six 45-foot grates, would be only 8⅓ hundredweights per grate per hour, which is about one pound per foot of grate slower than an ordinary destructor having 25 square feet of grate and burning 6 tons in 24 hours.



PLAN OF BOILERS AND DESTRUCTOR FURNACES AT THE ROCHDALE SANITARY WORKS.

This is altogether too slow for a forced blast grate, and it would be necessary to stop one unit of plant, as otherwise, even with a blast equal to half an inch of water, the grates could not be kept covered. By stopping one unit of plant, the remaining two would have the 50 hundredweights between them, or 12½ hundredweights per 45 feet of grate, which would come out to only a little over 32 pounds per foot of grate, which is slow enough for a forced blast grate. This method of working would require a large number of storage tanks, and I am not sure that plenty of boiler room will not, in the long run, be the better of the two arrangements. I fully understand the advantages which, it is said, thermal storage tanks will give us, if used on a large scale, but I do not think that in practical working in a refuse electric lighting station they will be able to come up to expectations.

We will now see what can be done in thermal storage with the two boilers which comprise our unit of steam plant. Suppose we take the difference between maximum water level and minimum level at 5000 gallons per boiler or 10,000 gallons in the two boilers. This can all be evaporated down to the lowest water level during the heavy load, without feeding water into the boilers during that critical period. The heat stored per boiler in these 5000 gallons of water is between the 53 degrees Fahr. temperature of the feed water in the tests before referred to, and the temperature of steam at 113 pounds pressure, viz., 346 degrees, and amounts to 50,000 × 293 = 14,650,000 units.

The heat absorbed in evaporating water at 346 degrees into steam at the corresponding pressure amounts to 873 units per pound; therefore,

$$\frac{14,650,000}{873} = 16,781$$

pounds extra evaporation, due to the stoppage of the feed pump. If this quantity be divided over the five hours previously taken as the period of heavy load, it gives 3356 pounds of water per

hour, available for power purposes in addition to the 79,615 pounds previously mentioned.

According to one test, 350½ gallons were directly evaporated, and if we add to this the extra water which may be evaporated when the feed pump is stopped, viz., 335.6 gallons, we get 686.1 gallons per boiler, available during the 5 hours of heavy load. This is without going beyond the 113 pounds working pressure; but if the storage pressure were higher than the engine working pressure, the result would be still better.

The cost of stoking plant of this description may be taken at 1 sh. per ton of refuse burned. Destructor work, as a rule, is always hot and heavy, and when steam production is added, the men have to pay some attention to the steam gauge as well as perform their heavy manual work. It must not be thought that because refuse is abundant no care is necessary in making the arrangements for burning it and in keeping the appliances in good order, for if one gets into the "anything-will-do" sort of way, unsatisfactory results are sure to be obtained in refuse utilisation.

It is well known that with forced blast a much smaller quantity of air is necessary for complete combustion than with chimney draught, besides obtaining the advantage of being able to burn a larger quantity of refuse per square foot of grate. With chimney draught I have never known refuse burned with double the theoretical quantity of air; it is oftener 4 or 5 times the latter, but with forced blast much better things may be done. A further result obtained by the blast is a much higher temperature in the cell and in the combustion chamber, and, as a consequence, much more steam is produced as well as a thorough consumption of the fumes and combustible gases. In other words, forced blast entirely dispenses with the necessity for a cremator, and when this is better understood and acted upon there will be fewer complaints about destructor chimneys. This arrangement can be fitted to any existing destructor, and, if put in under competent supervision, the results cannot fail to be satisfactory.

As to the completeness of the combustion and the smallness of the surplus air admitted into the cells, a large number of tests have been made where the carbonic acid gas was found to be over 13 per cent. by volume and as high as 18 per cent., and the fires can be kept under such control that, when the doors are open, there is no inrush of cold air to cool the furnace. Appended is a copy of two analyses of the gases, taken when the doors were all half open, the fires working in the usual way and the combustion fairly rapid. The gases were sampled and examined by the borough analyst.

	No. 1 Test. Per Cent.	No. 2 Test. Per Cent.
Carbonic acid	18.19	17.36
Free oxygen	0.96	1.90
Carbonic oxide	Nil.	Nil.

These results are by volume and it is particularly interesting to note that, although there was so little free oxygen remaining, there was absolutely none of the poisonous carbonic oxide present in the effluent gases. These tests were made to see how far the fire was under control. The result is one of which any engineer burning coal might justly be proud, and I am pleased to have been able, with such simple appliances, to get so near perfection.

During the past ten years I have done what I could to infuse some little enthusiasm into the question of refuse utilisation, and I am gratified to find that it is on the point of being tried on a large scale at a number of places for electric lighting purposes. These instances will be watched closely by other local authorities, and it is important that good results should be obtained, quite apart from the fact that the authorities immediately concerned are spending such large sums on the plant.

To come back to our own case, it has been shown that the water evaporated per pound of refuse may be anything between 1.43 lbs. and 1.874 lbs. under actual conditions, depending upon the method of working. I will put the water evaporated per pound of

refuse in the various tests together for comparison :—

	Actual Conditions. Lbs.	From and at 212 degrees Fahr.
No. 1 method	1.64	1.97
No. 2 "	1.81	2.187
" "	1.874	2 266
No. 3 " average	1.43	1.73
Coal test	5.60	7.33
Very poor refuse	1.36	1.64

In the last case the clinker was over 50 per cent. of the original refuse by weight. If we take the five results above obtained with refuse under actual conditions, add them together, and then divide by five, the average will be over 1.6 lbs. of water per pound of refuse. When the class of material used as fuel is considered, it will, I think, be granted that the results obtained are extremely satisfactory. After what I have said as to the weight of clinker obtained being from one-third up to over one-half of the total weight burned, I think no one will say that the refuse used was greatly above the average in quality. It is comparatively easy to burn light material with little mineral matter in it, but refuse containing over 40 per cent. of clinker is not unusually considered to be a good steam raising fuel.

However, I have attempted to show that this material, bad as it may seem, is capable of a considerable amount of work in the way of steam producing, and that it will do very decidedly more than pay the total costs of burning, which latter, at the same time, reduces the refuse to about one-third in weight, thus disposing of the other two-thirds in the most approved sanitary manner, viz., by fire.

The disposal of two-thirds of the refuse completely is an important matter, but when to this is added the fact that the remaining third is rendered quite free from any organic matter whatever, it is past conception that corporations and local authorities will continue to tip such immense quantities of putrefactive matter away, when, if they put in suitable appliances and used the steam which can be produced, the refuse might be burned and a profit made by the transaction. The tests I have made have been fairly conducted, the plant is extremely simple (some say too much so) and substantial, and there is no reason to doubt that it is able, if properly worked, to give results which must be for the public good.

THOMAS MUDD, M. INST. C. E.

Manager of the Central Marine Engine Works, West Hartlepool, England.

NOT the least famous of England's many marine engine building establishments are the Central Marine Engine Works, of West Hartlepool, which during the past seven years have turned out something like 230,000 horse-power of engines, and at the present time give employment to about 1500 men.

Of these works Mr. Thomas Mudd has the distinction of being general manager, having been connected with them from the first, in 1882, when the shipbuilding business of Messrs. Wm. Gray & Co., of West Hartlepool, was found to have developed to such large proportions that the firm decided to commence engine-building on their own account. Mr. Mudd was engaged as manager of the new enterprise, and was entrusted with laying out a plot of ground, nearly ten acres in extent, as a marine engine works of the most complete kind, with all the numerous subsidiary departments demanded by what was intended to be, and what since

proved to be, a thoroughly successful undertaking.

Mr. Mudd's engineering career began at the age of sixteen in the works of the Darlington Forge Company. At eighteen he occupied the position of sole draughtsman in one of the departments of the Northeastern Railway Company, at Darlington, and at twenty he became actively interested in marine engineering at the works of Messrs. T. Richardson, at West Hartlepool. For seven years he remained there, serving in the drawing office of this firm, and gathering a varied experience in engines and boilers for general merchant service.

At the end of these seven years he had become assistant manager of the works, and when, therefore, he entered into his engagement with Messrs. Gray & Company he had acquired just that kind of training which was best calculated to enable him to perform his new duties with credit to himself and profit to the new business.

The building of the Central Works was carried out during the years 1883 and 1884, and in the latter part of 1885 the first set of engines was turned out at the new establishment. Since then engines for over 200 steamers, mostly of large size, have been built there, and the records of all of them, in point of economy of operation, have been uniformly gratifying.

The reduction of coal consumption in the engines of cargo boats has, in fact, been one of Mr. Mudd's chief studies, and in his new five-crank triple-expansion engine, which he is now building for a Liverpool firm of ship-owners, and which is designed to work with 225 pounds boiler pressure, it is likely that something better even than 1.38 pounds and 1.4 pounds of coal per indicated horse-power per hour, previously obtained by him, will be achieved.

When the firm of Wm. Gray & Co., whose tonnage of ships built was, by the way, the largest in the British Isles in 1895, was converted into a limited company, Mr. Mudd was taken into partnership, and in 1894 was elected a director, still retaining the management of the Central Engine Works. In November of last year he was elected to the honourabe office of Mayor of Hartlepool and chief magistrate of the borough, and on that occasion the foremen and officials of the Central Works presented to him and his wife an appropriate address, beautifully executed and framed, conveying expressions of esteem, and their congratulations and sense of satisfaction at his elevation to that dignity.

Besides being a member of the Institution of Civil Engineers, Mr. Mudd is one of the Institution of Naval Architects, the Institution of Mechanical Engineers, the Northeast Coast Institution of Engineers and Shipbuilders, and of the Society of Arts. He is also a member of the council of the Institution of Cleveland Engineers, and an honorary member of the Institution of Junior Engineers.

A CONCRETE ENGINE FOUNDATION BLOCK.

By J. Hetherington.

A POTENT factor in the comfortable running of high speed machinery lies in a massive and trustworthy foundation to which the plant can be securely anchored. Where directly coupled engines and machines are of such construction and dimensions as to preclude an iron bed-plate, common to the whole, the foundation to which the separate items are fixed has to be answerable for the permanent alignment and consequent smooth running which would otherwise have been attained by a cast iron sub-structure, making practically one machine of the driver and driven parts. The foundation, in this respect, being made an integral part of the machinery, its construction, stability and quality are of first-class importance.

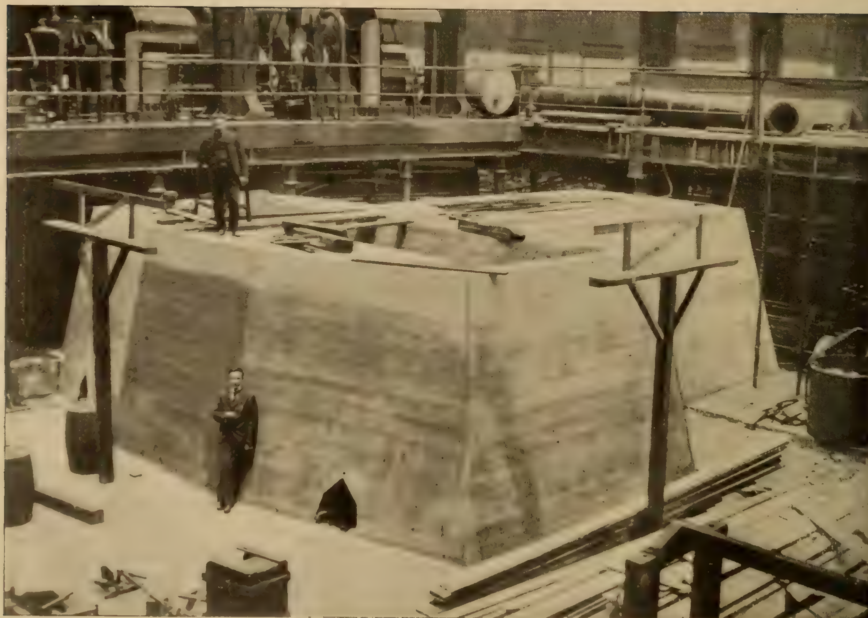
An installation in which the above conditions were to be observed was last autumn put into commission in the Deptford generating station of the London Electric Supply Corporation. This station is famous for many unique mechanical and electrical combinations, and the latest unit possesses many interesting peculiarities which have been fully chronicled in the technical periodicals.

As affecting the question of foundations, there is an engine, some 70 or 80 tons in weight, driving a three-throw crank shaft coupled directly to the shaft of the armature by a rigid coupling. This shaft is over 12 feet long, and carries a revolving armature nearly 40 tons in weight. The field magnet frames for this require a pit 22 feet long, 6 feet wide and 11 feet deep and add about 40 tons more. One bearing of this machine is pinned and bolted to the bed-plate of the engine, while the other is aligned with, and connected to, it only by the concrete foundation.

The speed at which the plant is run gives a circumferential speed to the armature bobbins of over 10,000 feet per minute, or nearly two miles. Such weights, moving at this velocity, require, for satisfactory working, perfectly linable bearings, which imply a foundation that will, once the bearings are right, keep them permanently so without vibration or other undesirable movement. Accordingly, unusual care was bestowed on the formation of the concrete block to which the above plant is bolted, with results satisfactory not only to the contractors for the dynamo and engines, but also to the corporation's engineer-in-chief, Mr. P. W. D'Alton, M. I. M. E., under whose directions the foundation was put in by the corporation's own workmen.

The site for the block is on a previously laid concrete floor, planned for 10,000 horse-power direct-driven dynamos (since abandoned), and at a level too low for the general purposes of the station, as well as for the sinking of a pit for the dynamo. On this account the foundation of the new unit is nearly wholly above the floor, being raised 10 feet, and is in itself an interesting bit of engineering work. The illustration on the next page gives an idea of the general aspect, size and situation, having been made from a photograph taken after the woodwork had been removed.

The first consideration in making the block was a thoroughly efficient bond to the existing concrete floor, which is about five feet thick. A clean, fresh surface was obtained by taking off a layer, one foot thick, over the whole



CONCRETE FOUNDATION BLOCK FOR A 1500 H. P. ENGINE AND A 1000 K. W. DYNAMO.

area to be occupied by the new work, while by slightly undercutting the margin, a dovetail was produced for keying the new work to the old.

A wooden mould, of the shape of the block, was made of 1 inch boards, nailed to battens, with vertical timbers, 6 inches square, at every corner and midway of the long sides. Horizontal timbers of the same section were spiked to the top of these, so as to tie the cross part of the T to the upright part, the plan being in the shape of a huge letter T, with the engine on the shank and the flywheel armature on the cross. Cross timbers of the same size were fixed on the tops of these to tie in the sides, and on the upper side of these the tipping floor was laid, commanding the whole space below.

On the under side of the cross timbers were arranged supports to take the tops of the bolt cores, so fitted that their accuracy could be checked as often as desired by reference to fixed points outside and altogether independent of the framing itself, and compensation could be easily made for any distortion caused by the dry wood absorbing moisture from the concrete. These reference points were on the upper edges of cross rails which are seen in the foreground in the cut above, and on the iron girders seen surrounding the other two sides of the foundation about two feet above the finished height.

Between these points fine lines were stretched, passing through ½ inch holes in the pieces *A*, Fig. 1, a saw cut from the holes to the lower ends of the pieces allowing them to be put on over the strings. Battens 1½ inch thick, fixed to the bottoms of these pieces, were bored at the proper places, as determined by the lines, and the bolt cores trimmed to fit the holes at one end and the plates at the lower end. This arrangement being lined so that the strings were in the centre of the holes in the pieces *A*, any movement could be at once detected and allowed for by the wood-screws above. Only ¼ inch on each side of the holding-down bolts was allowed in the concrete for grouting in when the engine and dynamo were correctly placed and lev-

elled, and every one of the 42 holes was found to be accurately under the corresponding holes in the bed-plate and bearing blocks.

wet and was necessarily dropped into the foundation from a considerable height at the beginning, gradually diminished as the work rose in the frame.

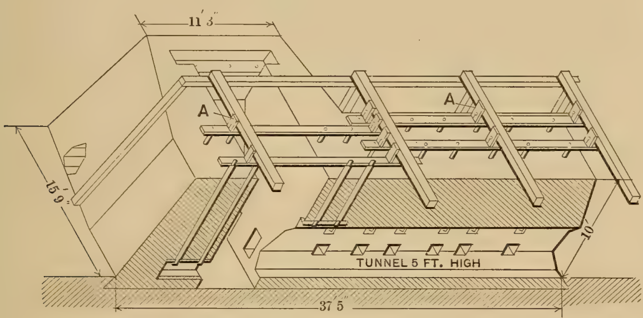


FIG. I.—SECTION SHOWING PART OF TIMBERING, BOLT CORES, ETC.

Portland cement of the very best quality was used in making the concrete, finely ground and weighing over 115 pounds per striked bushel (1.28 cubic feet) after quietly filling the measure, and with a tensile strength of 300 pounds per square inch after seven days' immersion. It was thoroughly cooled before being used.

The ballast was specially selected from dredgings from the river Thames and was remarkable for its freedom from any impurities detrimental to the proper binding of the mortar with the aggregate. As brought up, it contained too large a proportion of sharp sand, and the whole of it was screened, leaving a heap composed of particles of every size from sand up to flints from 6 to 8 inches long. After careful tests, to determine the interstitial space, the sand being somewhat coarse, the following proportions were used :—

Ballast	36	cubic feet
Sand	7½	" "
Cement	6	" "

This is equivalent to 7¼ to 1, or practically six parts of aggregate to one of matrix. About one-fifth of the total bulk of dredged material was left over as surplus sand, in excess of what was required. This was quickly disposed of to builders at current rates. The concrete was turned twice dry and twice

As the area to be gone over was very large, the starting point got fairly set before the men worked round to it again with a layer 18 inches thick each round, and in order to check the too rapid evaporation of moisture by the hot dry air of the engine room, water was sprayed over the surface of the layers at intervals from a hose pipe laid on for the purpose. Tunnels were moulded in the block to give access to the lower ends of the foundation

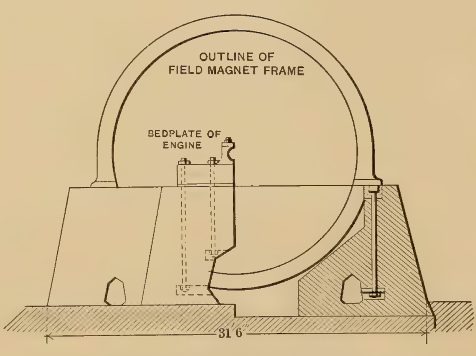


FIG. 2.—END VIEW AND SECTION THROUGH ARMATURE RACE.

bolts which connect to cast iron plates worked in as the concrete rose, and to provide an entrance to the armature race. The total quantity of concrete

in the block is 230 cubic yards, weighing about 390 tons, of which close upon 50 tons are cement.

Apprehension was felt that cracks would develop in the work as it hardened, due to the shrinkage of cement, and experienced concrete engineers had predicted that the finished block would not be a monolith. These fears have so far proved groundless, and the most careful examination at the points of weakest section and where contraction strains were most likely to accumulate, fails to reveal even a hair-wide crack, although the machinery has been daily running for some months. To all appearance, the block is as solid as if hewn in rock.

Current Topics.

MACHINERY builders who intend to cater to foreign buyers, especially to those in very far-off countries or in countries accessible only by roundabout routes, will serve themselves well if they will have an eye on the way in which their goods are packed for shipment. English builders are almost proverbially careful in this respect, with the result that what they ship generally reaches its destination in good order, and will operate satisfactorily when put to work, while the products of their less painstaking competitors—often Americans—come to the purchaser battered and broken, perhaps, with possibly some parts missing, and thus become at once annoying provocations to the man who wants them, and wants them in a hurry, with no time to spare to send perhaps thousands of miles for a duplicate piece, or even a new machine. There can be but one result from such an experience—the careful shipper will secure the bulk of the trade, even though his machinery may not be the best nor the lowest in price. The time which he saves for the purchaser, and the annoyance from which he relieves him, more than make up for the difference.

TAKE the case of an ordinary engine to go, say, to South America, as one engineer put it not long ago. The English builder will fix the engine to heavy skids, and build what will be, practically, a substantial house around it, strong and secure against all possible battering of a long voyage and rough handling. When this engine reaches

its destination there is little to be done to get it into shape for work. Everything is complete and in good order. The American builder, per contra, will, in most cases, secure the engine to the lightest skids that he thinks can be made to stand ; a flimsy bit of timbering will go around the outside, and the governor, perhaps will be wrapped up in some brown paper and tied on with a bit of string. Then the whole thing will be sent off with a trust in Providence that, unfortunately, does not always work in favour of the buyer. The engine is almost certain to suffer in transit, or the governor to be lost, and the builder's or shipper's reputation likewise. What is true of engines is true of all other machinery. The far-away purchaser naturally will prefer those goods which come to him with the least effects of travel wear and tear, and which can be put to work with a minimum of trouble and loss of time. There is a lesson in this which the export machine builder should heed.

One other thing which it will pay him to study is efficient representation in those countries in which he expects to find a market. Most people, before they buy a thing, want to see it—want to satisfy themselves, as far as they can, that it is what it is represented to be. The engine, or dynamo, or crusher, or whatever it may be, that can be shown on the spot, by sample, will often find a purchaser to whom merely an agent's description or a catalogue illustration would be more or less unsatisfactory. The builder whose agent has specimen machinery to show will always fare better than the one who trusts simply to pictures and to his reputation, however good and widely-known this latter may be in his own country. He should always bear in mind that the foreign purchaser may not know him, or even of him, and that the contemplated business transaction may be the first that is to be entered into between them. The character of the machinery itself, the promptness with which it reaches him, and the condition in which it reaches him, may be of infinently more moment to the man who is buying than a whole continent full of good reputation. And then the matter of catalogues. Catalogues for the Latin countries—in South America, for example—written in English are oftentimes quite useless, almost altogether so if brought into competition with a Spanish catalogue of some enterprising rival builder. Though English may be spoken and understood more or less, the mother tongue is preferred whenever possible, and the maker who tells of his wares in that tongue is more than likely to receive first consideration. To some extent this fact has been recognised, by English as well as American engineering firms, and catalogues written in the Spanish language are not uncommon. But, after all, they are the exception rather than the rule and might be profitably multiplied in number many times over.

An American engineer in England, writing, a short time ago, in the *Quarterly Review*, on his visit to some engineering works, says several things about machine tools there which, if not complimentary to English progressiveness in these lines, are probably in great part true. "There is to me," he says, "a wonderful lot of old machines at work. I am certain that this doesn't pay here any better than in our country. Machine tools that are thirty or forty years old are not a good recommendation to a manufacturer's reputation. One works that I saw contained a shaper by Nasmyth, made in 1837, and the owner said it was as good as any of the latest machines. He took evident pleasure in showing me a planer, certainly about 50 years old. He said that it did not, perhaps, plane quite so smooth as one of the new-fangled planers, but it did well enough for his work. Of course, I expressed great interest in these old tools, with the result that, instead of showing me any of his best machines, he went from one old tool to another

throughout the place. It was meant kindly on his part; but if I were looking about to spend money on machines, I think his order from me would all go on one page of his order book, with considerable space left. This appreciation of old tools here in England is one of the most distressing things that I have come across. An old tool is never thrown out because it is out of date. It may be too small, and not suited to the work, in which case it is sold to someone who doesn't know better. There is always a market for a machine, even if it were dated 1740 instead of 1840. Another very strange matter to me is to learn that even an old tool, made by a celebrated maker, will always sell at a good price at an auction. A friend told me, since I arrived, that at a sale he recently attended, a shaper by Whitworth, at least 50 years old, sold for the same money for which a new one could be purchased to-day. Perhaps they think the machines are like the name on them—they don't wear out, so why should the machine?" It is only fair to add to all this, however, that in some shops in all countries fossil methods and fossil tools are still preserved and used, and, indeed, often perform their offices quite as well as some of the latest creations of the tool builders' art. Where they fail in this, competition must, eventually, send them to the curio heap. Evidently, the time for this has not yet come everywhere, and until then shop relics will continue in use as interesting reminders of the ingenuity and excellence of work of a bygone generation.

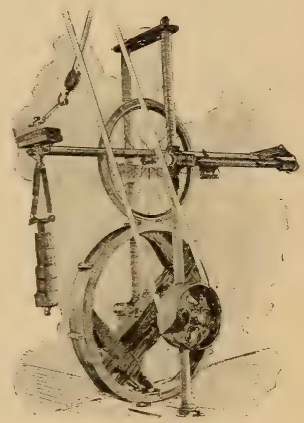
Some recently published rack railroad data show that altogether 70 lines of this kind have been built since 1812, and that of this number 17 are in Switzerland, 14 in Germany, 12 in Austro-Hungary, 4 in France, and 3 in Italy, while the remaining ones are distributed over England, Spain, Greece, Portugal, South America, Asia, Australia, and the United States. The combined length of all these lines is placed at about 500 miles, of which 188 are built on the well-known Abt system. The mechanical equipment of the lines comprises about 300 locomotives, ranging in weight up to a maximum of 70 tons.

Seventeen years ago the only semblance of a railway in the whole Chinese Empire was an iron tramway, about 10 miles long, at the Kaiping coal mines, 80 miles from the town Tien-Tsin. From a recent consular report by Mr. Sheridan P. Read, United States Consul at that town, it appears that small cars, loaded with coal, were pushed over this tramway by coolies, who received 10 cents in Mexican silver for 12 to 14 hours' work per day. About this time the works were placed under the charge of Mr. Claude W. Kinder, an energetic young English engineer, who at once ventured to propose many changes tending to increase the efficiency of the plant and to decrease expenses. The Chinese directors of the mines, however, did not regard his efforts with favour, and the Peking Government promptly vetoed his attempts at progressive measures. But, despite the Peking authorities and native superstitions, Mr. Kinder determined to have a locomotive, if he had to build it himself; and he did build it. Four small driving wheels were ordered from the United States; a disabled stationary engine furnished the boiler, and a broken-down winding engine the cylinders. With few tools and little outside help, these parts were fitted together, and the "Rocket" was at last put upon the track, with great yellow dragons emblazoned upon its sides. It was the first locomotive in China, and was a startling object to the Chinese, who expected all manner of dire consequences as the result of the innovation. The Peking authorties were horrified, and at once ordered the Rocket dragon to be summarily suppressed. But the Chinese mine directors permitted it to be used in short trips, inside the yard at first, and its travels were gradually extended

without producing the war, pestilence and famine expected. At last imperial permission was granted for its free use. This was the beginning of railways in China, and the builder of the first locomotive is now chief engineer and superintendent of the Imperial Railways of China.

A VERY good illustration of the saving effected by mechanical traction as compared with animal traction on street railroads is given in the report recently made to the Metropolitan Traction Company, of New York city, by its President, Mr. Vreeland. In this it is stated that the company now has 164 miles of single track, of which 25.34 miles are operated by cable, 6.78 miles by the underground electric trolley system, and 131.88 miles by horses. The net earnings of the one-fifth of the mileage which is operated by cable and electric traction were so large in 1895 as to carry the entire investment. "It is not only through an increase of business," says Mr. Vreeland, "that this is brought about, but also through economy in operation. When the entire traction system was operated with horses, the cost of operation was 70 per cent. of the gross receipts. The substitution of mechanical traction upon 20 miles of 122 reduced the cost of operation of the entire system to 54.39 per cent. The cost of operating the Broadway road was reduced from 66 to 38 per cent. by the substitution of mechanical traction for horses. These figures indicate very plainly what may be expected of this system when it shall be supplied with mechanical traction throughout, and be, in other respects, fully developed."

ONE of the best objections that has always been made against many laboratory tests of materials and apparatus is that the conditions under which they are conducted are not real, and that the results, accordingly, are deceptive. Every engineer knows how true this is, and appreciates the great importance of carrying out such experimental investigations under circumstances as nearly as possible like those which the machine or material is likely to meet in actual service. The closer the approximation, the more valuable the results, and, of course, *vice versâ*. Investigators, therefore, particularly in recent years, have given much attention to the perfection of testing machines and methods, so as to eliminate, to the greatest possible extent, the vitiating influences of artificial conditions, and in not a few instances excellent and very interesting provisions have been made with this end in view. One of the best of recent illustrations of this is supplied by the bicycle wheel testing machine which is used at the great American bicycle factory of the Pope Manufacturing Company, at Hartford, Conn., and of which a little explanatory sketch is given in this column. The machine is really very simple, and, yet, reproduces in a faithful way the worst possible conditions of service which a bicycle may be expected to encounter; in fact, the test conditions are made unusually severe, so that the wheel which comes out successfully from a trial may be accepted as a pretty staunch and reliable bit of mechanism.



A BICYCLE WHEEL TESTING MACHINE.

THE testing apparatus consists of a large wooden wheel, about four feet in diameter, on the circumference of which are a number of heavy cogs of unequal length and shape, varying in height from half an inch to two inches, some sharp at the ends, some rounded, the

purpose being to produce as rough a surface as could be found on even the stoniest road. Against this a bicycle wheel, with spokes taut, and pneumatic tire inflated, a brand new wheel fresh from the factory, is pressed by means of a bar on which it rotates. At the end of the bar hangs a heavy weight, so that the pressure on the bicycle wheel against the rough circumference underneath is equal to the weight of a rider of from one hundred and fifty to two hundred and fifty pounds. Having been thus weighted, the machinery is set in motion, the large wheel turning one hundred and sixty-two times in a minute, making the bicycle wheel turn against it as if it were being driven over the road at the rate of thirteen and a half miles an hour. Thirteen hours is considered a very good average for a wheel to last under this strain, though some wheels have been known to run along for thirty, forty, and even fifty hours, before giving evidence of any serious defect.

THE Cliff Paper Co., at Niagara Falls, are building a new power house, in which they will generate electricity for use in their paper mill. The company has a pulp mill, driven by two Leffel wheels, of 2500 horse-power, at the water's edge below the falls, and a paper mill on the top of the high cliff, thus securing a double service from the water, and bringing discredit upon the saying that "the mill will never grind with the water that is passed." Now this progressive company is about to take another step to practise economy, and it will adopt electricity, to succeed steam, to run its paper machines. When this proposed electric plant is installed, it will drive out three steam engines of a combined capacity of over 200 horse-power. Preparatory to the adoption of the electric current, the company will build a power house close to their pulp mill. The penstock leading to the pulp mill will be tapped, and a portion of the water diverted to run a 250 horse-power Leffel turbine, to which will be attached two 125 horse-power generators. The head water on this turbine will be 125 feet. At the top of the cliff will be two electric motors, of 100 horse-power each, attached to each of the paper machines; besides these, there will be two motors of 5 horse-power each, to furnish power for the small machinery about the mill.

AT a recent gathering of Pennsylvania road reformers in the United States, Mr. A. J. Albertson, an engineer who has done effective work in the reconstruction of roads in New Jersey, gave some interesting facts bearing on the progress of road reform in recent years. It has been proved, he says, that on sandy roads 30 bushels of grain are a load for two horses; on so-called pike roads 50 bushels are the maximum load; on macadam roads, 100 bushels; and on the best grades of telford roads, 200 bushels can be carried. If these figures be correct, and they probably are, they furnish an impressive argument for the improvement of roads.

A STEP bearing for an upright shaft, which has been in constant and satisfactory use for more than sixteen years, was recently mentioned in *The Engineer*, of London. The bearing is of phosphor bronze, and is loaded to about 480 pounds on the square inch. The shaft which rests upon it is 8 inches in diameter at the bottom, and, with the wheels, etc., upon it, weighs between 10 and 11 tons, running at 65 revolutions per minute. The cost of lubricating with castor oil has been about 2d., or 4 cents, a week. The step was put in use in 1879. The shaft was recently lifted, and it was found in excellent condition, the wear being only about 1-32 inch.

ANTHRACITE CULM DUMPS

Versus

NIAGARA FALLS.

AN

INDUSTRIAL SUPPLEMENT.

A GENERAL VIEW OF A PORTION OF SCRANTON.

CULM PILES VERSUS NIAGARA.

By Nelson W. Perry, E. M.

A QUERY comes to me from Scranton, "Can we compete with Niagara Falls in the distribution of energy by electrical means?" In order to frame an intelligent answer to this question I visited Scranton, and spent some days there investigating the conditions upon which depend in a degree the advantages possessed, or supposed to be possessed, by Scranton as a manufacturing centre, and I unhesitatingly reply that the cities of Scranton and Niagara Falls will never invade one another's territory by electrical power circuits until present methods of distribution are vastly improved, and there can therefore be no immediate competition of the kind implied. While energy can be transmitted to any distance desired by electrical means, its cost, when thus transmitted, increases so rapidly with the distance, that long before the Niagara wires have invaded Scranton's territory or Scranton wires, Niagara territory, the cost of power delivered will have risen beyond that for which it can be produced locally by coal carried from either centre to the point of delivery.

The fact is, therefore, that whatever the future may bring forth the question ultimately resolves itself into the one as to which of the two places can produce power locally the cheaper.

Niagara, with its enormous water power, now partly developed, has already attracted the attention of the whole world, and the promise of cheap power is held as an inducement to outside manufacturers to locate there or in the vicinity. The question which concerns us is, therefore, can the city of Scranton offer equal or better inducements of the same kind? If this be so, then there may be a strong competition between the two cities in the way of bids for the location of new industries within their immediate vicinities.

Your coal mines have from their opening been throwing away material which this generation is beginning to appreciate as of value, and as the old tailings from the silver mines have been worked over with profit, you are beginning to work over the culm piles from your coal mines and to appreciate their value.

When we bear in mind that every ton of these culm accumulations has not only been paid for by those who have used the more marketable coal from which it was a refuse, but that it is occupying real estate which is growing more valuable every day, we see that in these accumulations, if they are utilized, there is a source of potential energy which, if less inexhaustible than that of Niagara, is still available.

Since it has not only been paid for but is a cumberer of the ground, and furthermore has been proved to be a valuable fuel when properly utilized, the question has naturally arisen whether or not it can be utilized for the generation of steam power in competition with the power developed from Niagara Falls.

As to the available quantity of this culm perhaps the most reliable estimate is that given by the commission appointed by the Governor of Pennsylvania to investigate and report on the waste of coal. This commission, at the date of its report, May 20, 1893, consisted of Eckley B. Coxe, Heber S. Thompson and William Griffith, but during its active existence has had the official assistance of P. W. Shaefer and J. A. Price, who were removed by death. The standing of all of these gentlemen was such as to give any conclusions arrived at by them the full force of authority.

After estimating the proportions of the total mined coal that was wasted on the dumps in a number of the leading collieries, which varied from 19.7 per cent. to 74 per cent., they say :

"Taking into consideration that the per cent. of coal now sent to the dirt bank is much less than formerly, and the annual production greatly increased, it perhaps would not be unfair to estimate that since the commencement of mining the coal and coal dirt sent to the culm banks has been 35 per cent. of the total production, say 315,700,000 tons."

Mr. Wm. Griffith, under date of April 20, 1892, contributed an article to the *Colliery Engineer and Metal Miner*, in which he estimated on a basis of 20 per cent. waste that the amount of clean coal that went to the culm bank in the Scranton District alone up to and including the year 1891 was 21,975,444 tons.

The estimated total production of this district for the year 1891 was 6,193,390 tons.

The output for 1895 will amount in round numbers to 7,000,000 tons. If 20 per cent. of this goes to the culm bank, there is a stream of energy flowing to that repository of 1,400,000 tons.

Emery estimates 14.4 tons of coal per annual H. P. for 365 days of 20 hours each for simple high-speed, non-condensing engines. (Note 1.)

If we assume that the fuel value of this coal when recovered is but 78 per cent. of that of the best freshly mined egg, stove and chestnut, this 14.4 tons becomes 18.5 tons (Note 2), and the 1,400,000 tons now going to the culm heap represents a stream of energy equivalent to 75,672 annual H. P. This is nearly equal to the maximum estimated capacity of the great Niagara tunnel. But in addition to this as yet practically unutilized flow of energy, there is that vast amount already stored up in the culm banks during the years previous to 1892, estimated at nearly 22,000,000 tons (see ante), which on the same basis is equivalent to over 1,100,000 annual horse-power, the storage of which has in one sense, at least, already been paid for.

This annually increasing flow of energy may not inaptly be called the Falls of Scranton, which, unlike the Falls of Niagara, have not as they passed by dissipated their energy, but which have in succeeding years stored it up in an available form for utilization at our pleasure.

Some of the industrial establishments at Scranton obtain their culm from their own mines. One of the largest of these is the Lackawanna Iron and Steel Company. This company charges itself a nominal sum of ten cents per ton for the culm it uses, and it is shovelled into the furnaces just as it comes from the breaker.

The Scranton Illuminating, Heat and Power Company owned a culm pile which was in the way of the Central Railroad of New Jersey. The Railroad Company were glad to remove the culm, and entered into a contract to supply an equivalent amount as wanted. This they have been doing for years, delivering the culm for nothing at the doors of the electric lighting station.

The Suburban Electric Light Company also owns a culm pile, at the base of which its station is built. Allied interests are engaged in preparing this culm for market. The refuse is carried by conveyor into the boiler house of the lighting station, and costs very little indeed.

Other cases might be cited where industrial establishments located at the culm pile get their fuel for so nearly nothing as to make it an item of almost no consequence in the cost of their power.

The cost to other establishments located not so favorably is greater, so that we may assume the average price of culm delivered at the boiler house, where favorably located, will not exceed 35 cents per ton.

Note 1.—(Emery on Cost of Steam Power, Trans. Am. Inst. El. Engineers, Vol. X.)
Note 2.—(Wm. McClave in paper before Anthracite Coal Operators Asso., Phil., Jan. 9th, 1895.)

When culm is spoken of in the culm bank it refers to all of the material both large and small, but when it is spoken of in the boiler house it means simply the refuse, including dust and finer coal after the larger sizes have been separated out. These larger sizes, including buckwheat and pea coal, command higher prices.

The refuse—strictly speaking, culm—is the fuel preferred by the manufacturers in Scranton, except where the haulage costs too much, when bird's eye, buckwheat or even pea coal are preferred, but all of the steam raised in this district is raised by the combustion of the products from the culm bank, and by far the most of it from the refuse or true culm.

Mr. William McClave, in the paper before referred to, in comparing the fuel values of different fuels, rating egg, stove and chestnut coals of good quality at 100, places No. 1 culm at 78 and No. 2 culm at 70 per cent. By No. 1 culm is meant a mixture containing anthracite dust with Nos. 1, 2 and 3 buckwheat, and by No. 2 culm a mixture of dust with Nos. 2 and 3 buckwheat. According to his figures it would require 28.2 per cent. addition to No. 1 culm and 42.9 per cent. addition of No. 2 to make them equivalent in value to good quality egg or stove coal. By increasing the grate areas of the boilers the boiler capacities, even with these low grade fuels, need not be materially increased.

In a water power where the price of fuel does not enter, the influence of the fixed charges are controlling to a greater extent than they are in steam generated power. It is for this reason chiefly that water powers may be more expensive than steam, if the output is small, compared with the legitimate expectation of the investment, and may be less expensive where the output equals the expectation.

While I do not wish to depreciate the value of water powers (nor does any other engineer), I wish to correct a popular impression that water powers are necessarily cheaper sources of energy than steam powers. As between the two, for equal load factors, we have usually a larger original investment for water powers upon which we have to pay the interest in lieu of coal, and a smaller investment in the case of steam with the cost of coal and labor, etc., added.

If steam is to compete with water, it is, of course, a great advantage to have cheap fuel—not so much for the reason popularly supposed that the fuel bill itself is the governing factor in the cost of steam power, as for the reason that a cheap fuel enables us to reduce the original investment upon which the fixed charges are based.

Sir William Thomson (now Lord Kelvin) enunciated a law for the most economical size of conductors for the transmission of electrical energy, that "the interest on the investment in copper should just equal the cost of the energy lost in transmission." This is known among electricians as "Thomson's law," but it has a very much wider application than that to electrical conductors. It is merely a specialization of the old saying that one must not spend more for economy than the economy amounts to, and is an economic law—applicable to all the affairs of life.

Applied to steam power, we see its application in this: If fuel is very expensive, we can afford to make a large investment in the way of improved boilers and engines, because by their use the saving in fuel may more than counterbalance the increased interest on the more expensive plant. The same plant which would be economical where fuel were dear would not be economical where fuel were exceedingly cheap, simply because of the fact that the saving of fuel effected by the expensive plant would not offset the cost of the increased consumption of fuel of a cheaper plant. It is not necessary to follow this reasoning out through all of its applications to the cost of power, but it leads to the conclusion, which is well verified by experience and now recognized by our most advanced engineers, that where fuel is cheap it does not pay to go to extra expense to save fuel; viz., it

does not pay to go into extra refinements in steam engineering, because they cost more than they save.

Considering the question of original investment therefore, simply from the fuel standpoint, it is apparent that the cheaper the fuel the less we can afford to pay for its saving. This means cheaper boilers and cheaper engines—less original investment and less fixed charges.

But what is most important just now is to arrive at the actual cost of a horse-power at Scranton under usual conditions of working. The data most available for this purpose are contained in some tests which were made under the supervision of a committee from the Scranton Engineers' Club. These tests were made under working conditions in two of the largest establishments in that city, and under other conditions which were intended to yield fair and unbiased results. As far as they go I believe them to be thoroughly reliable.

In these tests the actual quantity of fuel used, and the quantity and cost of water and labor per H. P., were carefully determined. I have used these data of actual practice, and in order to arrive at the total cost of power have estimated the fixed charges as follows : I have assumed that on account of the lower grade of fuel the boilers can only be pushed to 85 per cent. of their capacity with good coal. The boilers in the L. I. & S. Co.'s works are the Babcock & Wilcox make, and estimated at $25 per H. P. The actual cost of those in the Dickson Manufacturing Company's shops, erected, is $16. We have therefore

Cost per H. P. 24 Hours per Day for 365 Days.

	L. I. & S. Co.	Dickson Mfg. Co.
Boilers	$29.41	$18.82
Buildings and chimney	15.18	15.18
Engines, simple high speed non-condensing	17.50	17.50
Total	$62.09	$51.50
Total, with 2½% for loss of interest during construction	$67.37	$55.88
Insurance, taxes and renewals 5%, and interest on investment 6%	$7.41	$6.15
Water	2.34	2.52
Firing	5.91	3.62
Removal of ash	2.45	0.95
Total cost per annual H. P., exclusive of fuel	$18.11	$13.24
Cost of fuel	4.94	$8.30
Total cost per annual H. P.	$23.05	$21.54

The above figures are for an annual H. P. 24 hours per day and 365 days in the year. From these data I have calculated the cost of 10-hour power for 313 days in the year, assuming that the consumption of fuel for 10 hours will be 52.38 per cent. of that for 24 hours, and that the cost of labor and water will be 50 per cent. The results are as follows :

COST PER H. P. FOR 10 HOURS A DAY FOR 313 DAYS.

	L. I. & S. Co.	Dickson Mfg. Co.
Fuel	$2.23	$3.73
Water	1.00	1.09
Firing	2.54	1.55
Removal of ash	1.06	.42
Fixed charges	7.41	6.15
Total without coal	$12.01	$9.21
Total with coal	$14.24	$12.94

Comparing these figures with those at Niagara, the Niagara Falls Power Company officially announced that they had closed a contract with a customer near by for 1000 H. P. delivered at $20. This, of course, does not include the conversion of that power into utilizable form, and there must be added to this fixed charges on the cost of transformers and motors, building, labor, etc., to make it comparable with the figures above. If we assume the necessary translating devices as costing $30 per H. P. erected and charge as above 2½ per cent. for inspection and 6 per cent. for loss of interest during construction and only $8 for building, the invested capital becomes $41.23. If we charge for insurance taxes and renewals, 5 per cent. and 6 per cent. interest on the investment as before, we have a charge of $4.54, which must be added to the 20, making the cost per annual 24-hour H. P. to the customer at Niagara, without including anything for labor or losses in conversion, amount to $24.54.

But the power must be transformed, whether for lighting, power or metallurgical purposes, and the efficiency of this transformation cannot by any possibility, under working conditions, be greater than 95 per cent. The customer will, therefore, have to pay $25.83 per H. P. Ninety per cent. would be more probably the efficiency under the most favorable conditions, and this would bring the cost to the customer up to $27.26, which is considerably higher than the figures obtained for Scranton.

But the Niagara customer is compelled to buy power in 1000 H. P. lots, in order to get it at this price, and he must pay the same for it whether he uses it 10 hours a day or 24 hours. If the Niagara customer only uses his power 10 hours a day, it costs him more than double as much as it would at Scranton.

To a manufacturer who cannot use his power continuously for 24 hours in the day and 365 days in the year, and no one can, it would seem that Scranton unquestionably offers better inducements than does Niagara Falls. No electrical station in this country has a load factor as high as 50 per cent. It would seem, then, that if electricity is to be generated for transmission purposes, it can unquestionably be generated at Scranton or elsewhere in the coal fields to better advantage than it can at Niagara Falls.

The prosperity of a community depends not so much on the acquisition of one or two large industrial establishments using, say, 1000 or 2000 H. P. each, as upon the acquisition of a large number of establishments of varied character using from 100 H. P. up to 1000. The ability to generate power cheaply in small units, is, therefore, another advantage offered by Scranton.

Surveying the field from the standpoint of this paper, it would seem that under the conditions Scranton can to-day offer better facilities and inducements to a variety of industries than Niagara Falls has as yet offered, as well as better than at present she can afford to offer.

THE BOARD OF TRADE BUILDING, SCRANTON, PA., IN COURSE OF ERECTION.

THE INDUSTRIAL PROPOSITION OF SCRANTON, PA.

Susan E. Dickinson.

THE question of cheap fuel, which the economic conditions of the country have made of the utmost importance of late years to manufacturers, has brought about scientific investigation of the comparative cost of power for operating machinery as between Niagara and the culm banks of Pennsylvania. This investigation necessarily brings the city of Scranton into the foreground of the discussion, practically, whenever new enterprises are started or old ones are seeking a more favorable location.

That power can be much more cheaply generated by steam from the culm banks at the mines in the anthracite region than from Niagara it has been the work of scientific experts, who make report on other pages of CASSIER'S MAGAZINE, to show. This being shown by them, Scranton then rightfully makes claim to possession of the greatest inducements for manufacturers and other business men to bring to it their various enterprises and make it their home. In dealing with these questions there are many points of view from which the thoughtful man considers his proposed new location. Scrantonians invariably and cheerfully invite fullest scrutiny of their claim that their city, considered in relation to its fuel supply, offers the best opportunities possible for the manufacturer; and that, considered from every other point of view, it offers such advantages, social, educational, religious, in addition to beauty and healthfulness of location, as meet the wishes of those most desirous for the best opportunities in these things for their families.

Scranton's supply of culm is practically inexhaustible. Culm has been piled up from the mines in the Lackawanna Valley since 1828, when anthracite mining began. It must continue to be dumped from the coal breakers so long as anthracite coal mining shall continue. Dr. Leopold Damrosch, a few years ago, looking upon them from a mountain slope, which commanded a view of the "twin valleys" of Lackawanna and Wyoming, said: "Those culm piles are harsh discords in your glorious symphony of Nature." But already has the way been found to resolve them into harmonies—the harmonies of industrial wealth and of happy homes resultant from it.

The actual immensity of these great culm piles is shown in the illustration that throws one of them into the foreground of a perspective view of the city. Their comparative conspicuousness, in the city's 12,200 acres of incorporate limits and in the valley which stretches northward sixteen miles to Carbondale and southward ten miles to Campbell's Ledge, is but small. It is only as you walk or ride out into certain suburbs, or come into the city along the line of certain railways that you are made aware of them at all. But when they are seen at close range and the mind realizes that every square foot of these frowning black mountains is a wealth of fuel ready to be turned into steam, their very ugliness takes on a phase of grandeur. There is no calculable limit to the steam power hidden there and transformable also speedily into electric power.

The quality of Lackawanna culm as compared with that of the Schuylkill and Lehigh regions also adds to the inducements that Scranton holds out to the manufacturer. Its superiority results from its almost entire freedom from broken rock and slate; and this again is the result of the different pitch and formation of the coal veins in the upper and lower anthracite regions. In the Schuylkill and Lehigh sections the veins usually lie at sharp angles in the earth, and the slate formation runs regularly in alternate layers, at short intervals, between the layers of coal and both have to be mined together. The pitch of the chambers in which the miners work is such as to throw coal and slate together into the mine car standing on the gangway track below; and with these comes also of necessity any fall of broken rock when a portion of the mine roof gives way. There is no place in the mine where these veins lie to throw out there the useless slate and rock. As these must therefore be separated above ground in the breaker they all go into the culm heaps, largely diminishing the value of these as fuel. In the upper section of the coal region, of which Scranton lies in the heart, the coal veins are almost level, the slate layers are comparatively small, and the wide mine chambers, on a level with the gangway running to the foot of the shaft, or to the "cage" on which the car is lifted to the earth's surface, permit a large space to be utilized in dumping therein the slate and broken rock. This being required, the coal sent out to the breaker has but a small proportion of the unburnable admixture in it. The refuse being dumped in the mine, the culm piles outside are almost pure coal in the region thus favored by Nature.

In speaking of Scranton culm as fuel, it should be added that it can be used to great advantage without any preparation, although some users prefer a slight attempt at sizing it. It is to be remembered that the utilization for steam pur-

COURT HOUSE.

THE MUNICIPAL BUILDING.

poses has passed all experimental stages, and that it is coming into more general use with every successive year. There are at this time one hundred and twenty-five incorporated manufacturing firms in Scranton, representing many varied forms of industry, with $25,000,000 of capital invested in them. This is all outside of what is invested in coal mines. It is a fact that during the past two years of industrial depression Scranton has suffered less than any other city in the land. The failures in business have been very few, and the concurrent testimony of the great numbers of commercial travelers who visit this city has been that Scranton was the best business town in their territory.

The transportation facilities of Scranton for reaching all parts of the country with its manufactured products are the best. Ten railroads diverging from its limits put it in close communication with all sections of the land. The inland metropolis of northern and central Pennsylvania, it is but four hours from New York city and the sea. Its facilities for close communication with all the country immediately surrounding it are equally good. It has seventy-five miles of electric street car lines extending beyond the city limits into neighboring towns, boroughs and villages, besides twenty-nine miles of such lines within the city. Scranton was the very first city in the United States to introduce the electric railway in its streets ; and this, with its magnificent electric illumination at night, has given it the name, by which it is known the country over, of the Electric City. Strangers coming into Scranton during the evening, or at night, on any line of railroad are always struck with the brilliant and exquisite beauty of the

THE SCRANTON PUBLIC LIBRARY, ALBRIGHT MEMORIAL.

city illuminated by over 700 arc lights that mark out its streets and avenues, some stretching along level spaces, some climbing the hills eastward and westward. This night scene is one that never palls, never loses its attractiveness. Scranton continues to be acknowledged, as it has been for years, the best lighted city in the world in proportion to its population.

The population of Scranton, which the census of 1870 gave as 35,000 and that of 1880 as 45,850, nearly doubled itself in the decade following, the census of 1890 showing it to be 82,215. The most moderate estimate of its growth in the last four years places the present number of residents at 103,000. There have been more building permits issued during the last eighteen months than during any similar period of time in the city's history. The many blocks of handsome stores and office buildings it already contains are being continually added to by costly and architecturally beautiful ones, of steel and granite, many-storied and fireproof.

Beautiful residences multiply in the handsome residence districts of the city, along one tree-shaded avenue after another, "on the hill," rising gradually eastward from the business portion of the city ; over in Green Ridge, most charming of suburbs, stretching out to the north ; over in the old portion of the city, still known as Providence, lying west of Green Ridge. Over on the western side of the Lackawanna, that portion of the city where cluster its Welsh residents—famous through this country and Great Britain for their great choirs and their Eisteddfods—after getting away from the railroads and factories near the river, and crossing Main avenue, the business artery of that portion of the widely spread city, there lies another large space of comfortable, often handsome residences, along one street after another, bearing its evidence that Scranton also merits the title so justly and proudly claimed by Philadelphia, the metropolis of the Key-

stone State, of "a city of homes." The same is to be said of the South Side stretching down beyond Roaring Brook, on its way to the Lackawanna, for at least two miles, with the homes of the workers in the great steel mills, silk mills, and other factories. But with all these yet there is room, abundant room, for hundreds of thousands more of inhabitants, in comfortable homes, within the city's generous limits and the spaces open for it to add thereto.

Apropos of the wonderfully rapid growth of the city on a substantial basis, of the building of beautiful mansions, and of costly and many-storied hotels and office buildings, it may be well to advert to the security of foundations in Scranton. For there have been so many exaggerated, some wholly false, accounts of caves-in of the ground over mine workings sent out broadcast over the country by sensational correspondents that many thousands of people, who have never been in the anthracite region, really imagine that in Scranton we are all living in danger of being suddenly swallowed up as by an earthquake—at the very least, of waking in the middle of the night to find ourselves and all our belongings transferred bodily into some chamber or corridor of the mines. The actual truth of the matter in relation to the one not long ago widely described in this manner as occurring in a distant portion of the West Side, was that any one driving that morning through the entire section where this terrible thing was located would not have been aware of it.

Where mines have been worked out and abandoned, when the roof falls there occurs sometimes gradually, sometimes suddenly, a settling in of the earth above them. In the deeper veins these are so far below ground that the disturbance of the earth does not affect the surface at all. In the upper veins the disturbance is sufficient sometimes to cause a settling of walls, or more serious damage to buildings incautiously erected, without examination of the foundations, out in the suburbs where abandoned mine workings have not yet fallen in or been filled in. That all foundations are carefully looked to, except in such exceptional cases, the fact that level-headed capitalists who have lived here all their lives go on investing hundreds of thousands of dollars in such buildings as have been noted in this article, in spacious and costly churches, hotels, schools and other public edifices, is sufficient testimony. They would do nothing of the kind if there were the slightest danger that could not be averted by the most ordinary degree of care. Such settling as was to be expected has already occurred years ago, except in some occasional outlying district ; so long ago as to be almost a tradition of the early days.

Speaking of public buildings, Scranton has not less than seventy churches, many of them very beautiful in architecture, and thirty-seven graded public school houses, the actual cost of which was nearly a million of dollars. The new High School building, now nearly completed, is fireproof and will cost a quarter of a million of dollars. Directly opposite to it stands the Albright Memorial building, beautiful exceedingly, enshrining the Scranton Free Library of many thousand volumes that are being largely added to every year. The Green Ridge Public Library is also worthy of being singled out for mention for its unique and suitable character.

A beautiful and healthful location, with the "mountains set round about" it as round Jerusalem, with pure, free air, untainted by smoke or soot, with a water supply of unrivaled quantity and quality, these are some of the unquestioned possessions of Scranton. While bituminous coal makes every city in which it is used a "smoky city," anthracite coal is of totally different nature. The Sauquoit Silk Mills, the largest in the world, are located less than two hundred yards from the big boiler plant of the Scranton Steel Works ; and in warm weather, when the steel works are in full blast, the windows of the silk mills stand wide open all the day long without the slightest soil or injury to the delicate fabrics in process of manufacture as a result of their neighborhood.

NAY AUG PARK.

ROARING BROOK, NAY AUG PARK.

THE LACKAWANNA IRON & STEEL CO.—THE SAUQUOIT SILK MILLS.

The water supply of the city is inexhaustible, with a water-works supply of 35,000,000 gallons daily ; full supply available for a city of several times its present population. During the long, distressing drought of the late summer and early autumn of this year, while so many communities were in actual suffering from want of water, Scranton not only had an abundance of it, but one so great that no interdict was laid upon its people in the freest use of it, for flushing the streets and watering lawns and gardens, as well as for household use. It is the only place within a radius of hundreds of miles of it of which this can be said. Its quality is not inferior to its quantity, and its purity is most jealously guarded by Scranton's efficient health authorities. Its freedom from impure sediment and corrosive materials in solution is illustrated by the following letter from Mr. J. A. Lansing, president of the Scranton Stove Works :

SCRANTON, PA., October 4, 1895.

Miss Susan E. Dickinson, 430 Madison Avenue, City :

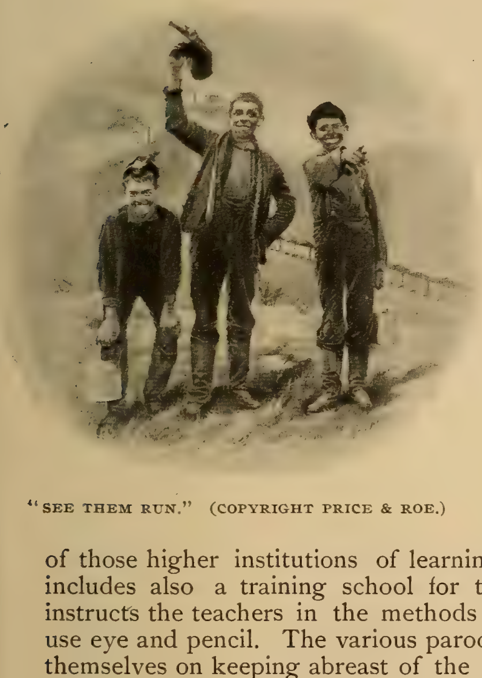
DEAR MADAM—Replying to your favor with reference to our experience with Scranton water as used in our boilers, we would say that we used a boiler made by the Dickson Manufacturing Company of this city, from 1867 to 1883, when we threw the boiler out to make place for a larger one. We were never troubled with scale, and so far as we could see, the boiler was in as good condition when we took it out as when we connected it up.

We have a boiler in use, set up at our old works in 1883, that was reported at the last inspection by the boiler inspector as absolutely free from scale or corrosion and, so far as he could see, in as good condition as the day it was connected up. Respectfully, J. A. LANSING, Prest.

Nay Aug Park, with its hundreds of picturesque acres lying along both sides of Roaring Brook, from where it leaps down over the romantic falls that give the park its name, is the city's possession, secured as a public park forever. From the iron bridge spanning the stream below the falls begins the seven-mile

boulevard, with a roadbed of shale rock, that has its terminus in the summer suburb of Elmhurst higher up in the mountains. Through pleasant woodlands, across wild ravines, around rugged cliffs this drive, unrivaled for pleasure in traveling it and unsurpassed in grandeur of view, takes its way. Below from point after point lie Scranton and the winding Lackawanna valley and, beyond, the West Mountain rises in stately dignity, crowning the long Western mountain slopes. An artist visitor from another State, who had but a year or two ago returned from Europe, recently declared in passing over this boulevard that its views were unsurpassed by any in the famous Austrian Tyrol.

In a different direction, an hour's ride or less on the Erie and Wyoming Valley Railroad brings the Scrantonian to Lake Ariel with the summer homes of many of Scranton's citizens set among the pines and on the upland slopes; and on one side, away from these, the charming picnic grounds beloved of Sunday schools and of the societies that delight in taking a day's outing together. In yet another direction, where the northern division of the Delaware, Lackawanna and Western Railroad passes through "the Narrows," just above the city, and emerges into a lovely farming region picturesque with its gentle slopes of vale and hill, there are to be seen for miles the pleasant summer homes of Scranton people; many more of them even than at Lake Ariel.



"SEE THEM RUN." (COPYRIGHT PRICE & ROE.)

To Scranton's thirty-seven large and handsomely built graded schools and the high school newly rebuilded and greatly enlarged this article has alluded. In efficiency of methods and instruction they hold their own in comparison with those of any city in the land. Side by side with graduates of the school of the Lackawanna, whose graduates are received by Harvard, Yale, Vassar, Wellesley, and other universities and colleges on certificate without further examination, graduates of the high school have been admitted to one and another of those higher institutions of learning. The public school system of the city includes also a training school for teachers, and a teacher of drawing, who instructs the teachers in the methods by which they are to train their pupils to use eye and pencil. The various parochial schools and the convent schools pride themselves on keeping abreast of the public schools. There are many kindergartens. Those of the Free Kindergarten Association have also a training school for Kindergarten teachers, which has graduated two admirably prepared classes and is now in its third year.

There is a successful technical correspondence school of mining and industrial arts, and two large and flourishing business colleges. The college of St. Thomas Aquinas and the Dickinson College Auxiliary School of Law have recently been opened and set successfully in operation. The Young Men's Christian Association and the Young Women's Christian Association have long had their winter evening classes. This year the "John Raymond Institute" of Manual Training with classes open to both sexes has been generously founded, endowed and placed under the auspices of these associations. Each of these has also a well furnished library, as has the Welsh Philosophical Society, and one is being gathered by the (Catholic) Young Men's Institute; all giving additional

facilities to those of the public libraries already named. Scranton, likewise, has reason to be proud of its fine Oral School for the Deaf, founded by the late lamented Emma Garrett of national fame ; of its hospitals, the Moses Taylor one, a bequest of that philanthropist, so much of whose business interests lay in and around this city, to the railroad men and steel workers ; and the Lackawanna hospital, partly supported by the State, partly by private subscription, and with a successful training school for nurses. The city has also four daily papers of high character and large circulation, a fair number of weekly publications, and one monthly, *The Colliery Engineer and Metal Miner*, of national reputation. Scranton, also, makes rightful and undeniable claim to being a musical centre. Brief mention has been already made of the great Welsh choruses, one of which took the leading prize at the Columbian Exposition competition, to which may be added their possession of fine soloists and more than one composer of well-known music. The German- repute. The principal churches are all possessed of noble organs, and have paid and well trained choirs.

BREAKER BOYS. (COPYRIGHT PRICE & ROE.)

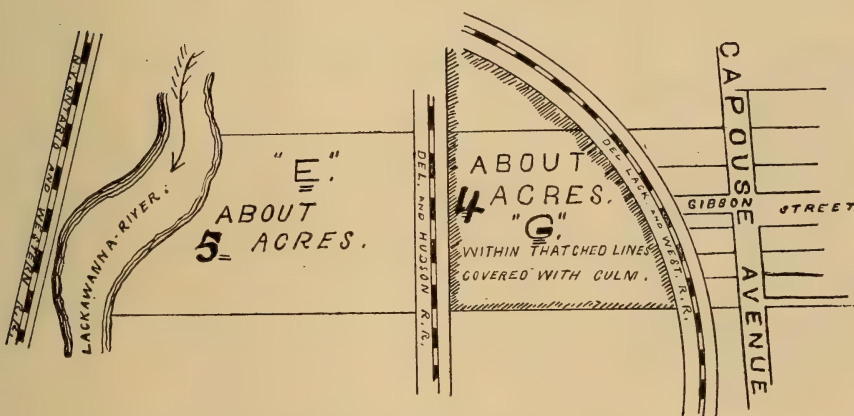
These things give full and satisfactory answer to the often asked question : "What society, what culture shall we find in Scranton?"

There is another point specially worthy of mention. The cosmopolitan character of Scranton's working population and that of its vicinity is well known. The Welsh people are all Protestants. The larger proportion of those who come hither from countries other than Great Britain are Roman Catholics. With so large an alien and often ignorant population sent us from less favored lands, the Catholic and Protestant clergy and their educated laity have always worked together in all fraternal feeling to raise the poor and untrained classes to a higher level. They work together, also, in the associated charities organization which performs its labors well in relieving suffering and preventing pauperism. St. Luke's Episcopal Church, the largest one of its denomination in the city, has at Lake Ariel a summer home for sick mothers and children who could not otherwise have such needful aid. It receives all who need to go irrespective of church connection, Protestants, Catholics, Jews. Seeing this, all these come up, voluntarily, to add to its funds. Never has it been necessary to make personal application for them. More than this might well be added, did space permit, to show the charm of Scranton's social life.

Going back to the subject upon which this article started, it may also be noted that if Mr. George Westinghouse, Jr.'s, new gas engine for utilizing 40 per cent. of the hitherto wasted power of coal and culm be what he claims, then all that has been said of Scranton's ability to furnish fuel, steam and electric power more cheaply than can Niagara, is but a modest putting of the truth which is more wonderful than anything heretofore dreamed of.

D. B. Atherton, secretary Scranton Board of Trade, will answer all communications.

View of Manufacturing Site and Culm Pile for Sale in Scranton.



Plot of above Manufacturing Site and Culm Pile.

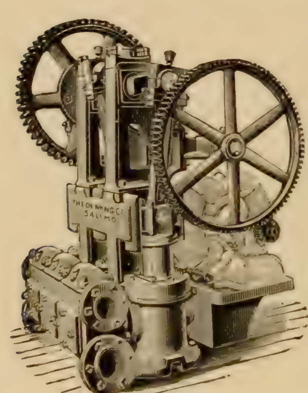
THE MANUFACTURING SITE of nine acres, as represented by the accompanying plot and picture, is located in the very centre of the city of Scranton, and is claimed by the owners to be the very best in the anthracite regions on account, not only of the abundant fuel which goes with the land, but because of the superior railway facilities provided by the site, and the unlimited supply of cheap labor in the immediate vicinity. The picture shows a portion of the large mass of anthracite culm, containing several hundred thousand tons of ***BEST STEAM FUEL.*** It also shows a small portion of the land, and two of the grand trunk railways of the country, the "Delaware, Lackawanna and Western," and the "Delaware and Hudson." The plot shows the location of these railways, as also of the "Ontario and Western," the culm site and the clear site for manufacturing plant. At the purchase price for all, the fuel can be placed under the boilers for ***LESS*** than ***25 CENTS PER TON.***

W. GIBSON JONES, Scranton, Pa.
MEREDITH L. JONES, 120 Broadway, New York. } ***Owners.***

MODERN PUMPING MACHINERY.

THE discriminating purchaser of Pumping Machinery will consider carefully these two points : The initial cost of the plant and the economy of every-day operation, and he will also bear in mind that machinery of defective design, low grade workmanship or non-adaptation for its duty is a prolific source of annoyance and loss.

This article has been suggested to the writer by a visit to the complete and extensive factory of The Deming Company, Salem, Ohio, where is probably made the largest variety of pumps for all purposes in the United States, but it is desired particularly to mention this company's Triplex Electric and Power Pumps. For all kinds of pumping, where the motive power is obtained from Water-wheels, Steam, Gas or Oil Engines or Electric Motors, these pumps are all that could be desired. They are adapted for boiler feeding, pulp, paper and fibre mill work, hydraulic elevator service, maintaining hydraulic pressure in refining and other processes for shaft and drift mines, for water-works and for many other purposes.



In the design of the Triplex Pump the principle of uniform discharge is considered. To illustrate : A Double Plunger Pump or a Double Acting Pump has two points in each revolution at which no water is discharged ; consequently, the variation from the maximum flow to no flow of water is 100 per cent. of the discharge. This variation is counteracted in part by air chambers, but the shock or hammer of the moving water injures the pump and absorbs without doing useful work, a large per cent. of the power applied. In the Deming Triplex Pump, however, the variation from uniform discharge is but 15 per cent. from maximum to minimum in one revolution of the pump shaft, and almost the entire power applied does useful work in pumping. The design of the Deming Triplex Pumps embodies the best practice, prominent in which the following points may be noted : 1st—The strains in the crank shaft are borne between the plunger bearings (not outside of them), the valve of which is obvious. 2d—All crank shaft bearings are bronze. 3d—Most important to the speed capacity and life of the pump is the system of guiding the plungers above and outside of the water chamber. Arranged thus the guides can be easily lubricated and maintained in repair and the plungers kept in line. 4th—Valve areas are ample, and all valves may be readily inspected.

The manufacture of the Deming Triplex Pump is carried on under competent superintendence. None but the best materials and workmanship enter their construction. Special tools and machinery are used, so that all working parts are interchangeable.

The engraving shown herewith illustrates one of the Triplex Electric Pumps.

THE DEMING COMPANY,

Salem, Ohio.

RAINBOW PACKING.

FAC-SIMILE OF A ROLL OF RAINBOW PACKING. NONE GENUINE WITHOUT THE TRADE-MARK. THE WORD "RAINBOW" IN A DIAMOND IN BLACK.

Mr. Henry J. Reynolds, chief engineer of the steamship Northland, of the Northern Steamship Company and Great Northern Railway line, writes to the manufacturers of the "Rainbow Packing," as follows :

Mr. Charles H. Dale, President, Peerless Rubber Manufacturing Co., New York City.

DEAR SIR.—I have used "Rainbow Packing" for steam and hot water pressure of 266 pounds and 500 to 600 pounds respectively, and find it superior to all others. Before using "Rainbow Packing" I tried various other packings, including corrugated copper, and found that they would not hold. I therefore tried "Rainbow Packing" and can cheerfully recommend it as being the only packing for all high pressures in the market to-day.

Respectfully yours, HENRY J. REYNOLDS.

September 12, 1895. Chief Engineer Steamship Northland.

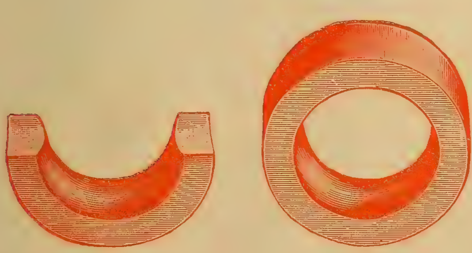
The cut at the top of the page reproduces the general appearance of a roll of the "Rainbow," both in color and the manner of stamping it with the trade mark. This packing is especially adapted for very high pressure, and is not affected by any degree of steam heat. It will not harden under any degree of heat or blow out under the highest pressure, and will make an air, steam, hot or cold water joint equally well.

It is not affected by oils, ammonia, liquors, steam heat or alkalies. Unlike Plumbago and Usudurian, it will not harden or crack. Joints can be made and broken in one-eighth the time consumed with packings that harden, as a tool is not required to break or face off joint.

Steam heating companies can make thousands of joints in new plants without the use of steam, with the assurance and guarantee that when steam is applied every joint will be perfectly tight, saving the labor of baking and following up, etc., as is the case when Usudurian or Plumbago packings are used, thereby saving from 100 to 300 per cent. in labor and time.

Joints should be faced with Plumbago-Lampblack or chalk. This packing can be taken out and repeatedly replaced.

It is made in rolls and sheets, $\frac{1}{32}$, $\frac{1}{16}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$ inch.

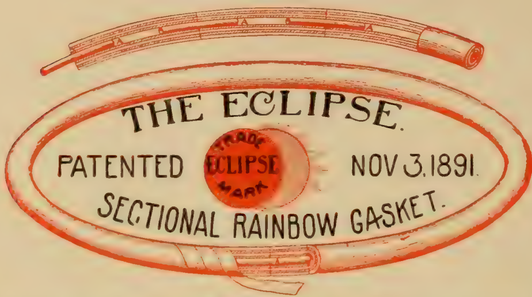


The trade mark consists of the word "Rainbow" in a diamond in black, extending through the entire length of each and every roll of Packing and is secured and owned exclusively by the Peerless Rubber Manufacturing Company, 16 Warren street, New York.

The Rainbow Gauge Glass Rings, shown in the accompanying cut, is red in color like the Rainbow Packing, and is made in the following sizes : $\frac{1}{2}$ in., $\frac{9}{16}$ in., $\frac{5}{8}$ in,, $\frac{11}{16}$ in., $\frac{3}{4}$ in.

This is something new in the line of Water Glass Packing, and fills a long desired want to the users of this class of goods, viz., a Gauge Glass Ring or Packing, so constructed that it will prevent the breaking of the glass tube under any con-

ditions, whether out of plumb or otherwise. It always remains soft and yielding and does not become hard when brought in contact with a high degree of heat. The displacement which takes place when screwing up the gland being all on the inside of the Rainbow ring allows the glass tube to take any position without any strain or leverage on it, thereby obviating many troubles which engineers are well aware of.



Three-eighths inch for Pipe Unions, ½ inch for Hand-holes, ⅝ inch for regular size Man-holes, ¾ inch for large size Man-holes. The Eclipse Sectional Rainbow Gasket for steam boilers is red in color and composed of the celebrated Rainbow Packing Compound. It will not harden under any degree of heat or blow out under the highest pressure, and can be taken out and repeatedly replaced. Joints can be made in from three to five minutes, and any size of gasket can be made instantly.

Dealers who have not carried gasket in stock, owing to the numerous and unsaleable sizes, will appreciate the Eclipse, as they will, with two sizes only, have a stock more than equalizing hundreds of sizes of the old style, with absolutely no waste or unsaleable stock, all pieces, no matter how small, can be formed on the lead tubes, into a sectional gasket, as shown in the cut.

Users of gaskets will appreciate the experience related in the following letter:

WINONA, MINN., April 17, 1895.

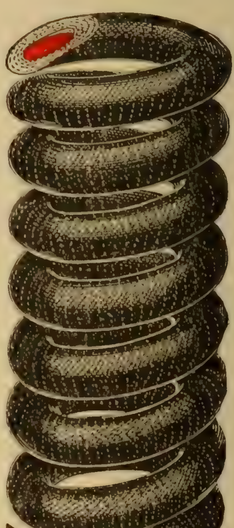
The Peerless Rubber Manufacturing Company, 16 Warren Street, New York.

GENTLEMEN.—Replying to the inquiry of the 4th, from Mr. Thorpe, concerning Eclipse Gasket Packing, I would say I have been using it for over two years, and wherever I have tried it it has given me the best of satisfaction. I have had it last on a man-head over a year, where the head is off every two weeks.

The first time I tried it was on the head of a heater over 44 inches across, where I had used every kind I knew; it would always leak if the pressure ran up over 100 lbs.

I made a joint with the Eclipse over two years ago and it has never bothered me since. Yours truly,

W. L. RAYMOND.



Peerless Spiral Piston and Valve Rod Packing. Owing to the repeated demands of consumers, the Peerless Rubber Manufacturing Company are now making the Peerless Packing in Spiral shape, shown in the illustration. It is in all other respects the same as the regular Peerless Packing. The story of the standing of this packing with users is told in the following letter:

LA CROSSE, WIS., April 13, 1895.

GENTLEMEN.—In reply to your favor, would say that I have used Peerless Packing for the last eight years, and find it the best packing I have used so far. I have tried many other brands, as well as two different makes of metallic packings, but finally had to come back to the Peerless as the most durable and economical; in fact, it is the only packing that we get satisfaction with in our steam feeds. Yours very truly,

ALEX. M. PAUL, Chief Engineer.

Steam users who desire to practice the little, but necessary economics which the use of proper packing represent, and which go far toward swelling the dividend account, should write for further information to the Peerless Rubber Manufacturing Company, 16 Warren Street, New York.

INDUSTRIAL

SUPPLEMENT.

DEVELOPMENT OF THE WATER TUBE BOILER.

THE first Water Tube Boiler that history mentions was built by Hero of Alexandria. During the past century the brightest engineers in the world have been constantly striving to perfect a steam generator of the water tube type, and the history of the attempts and failures to reach this goal would fill volumes. During the past twenty-five years success has been very nearly attained by several determined, tireless investigators—so nearly, in fact, that while none have been perfect, yet they have been good enough to be classed as "commercial successes," their faults being more than overbalanced by their virtues. Still, the army of investigators, experimenters and designers, realizing these imperfections, have continually labored to overcome the difficulties still present, and produce a water tube boiler which should be :

1st.—Absolutely free from danger from explosions.

2d.—With heating surfaces so thin that the maximum amount of heat might be absorbed from the impinging gases per sq. ft. of surface.

3d.—To concentrate great power in small spaces.

4th.—So designed that a minimum amount of labor was necessary for examination, cleaning and repairs ; and

Lastly, while using nothing but the very best of material and the highest grade of workmanship to yet reduce the first cost of the product to a reasonable point.

It was reserved for John Cahall, the Manager of the Boiler Department of the Aultman & Taylor Machinery Company at Mansfield, Ohio, to unite all these points in one boiler, which was christened in his honor The "Cahall," a description of which will be mailed by H. E. Collins & Co., Bank of Commerce Building, Pittsburgh, Pa., upon request.

The Carnegie Steel Company of Pittsburgh, The Illinois Steel Company of Chicago, and many other important iron and steel manufacturers of the United States have given this make of water tube boiler a thorough trial, and the results obtained in comparison with other types have been most satisfactory. In nearly every branch of manufacture the most prominent and progressive concerns have taken up, investigated and adopted for their use boilers of this type. The luxury of having water tube boilers in use that are always ready for operation, respond quickly to all demands made upon them, no matter how sudden or severe ; that will return to the owners in hot, dry steam a fair equivalent of the fuel consumed ; that will run day after day, month after month and year after year without delay, accident or annoying breakdowns, is such that, after having once enjoyed it to its utmost, as they do through the use of these boilers, they purchase nothing else thereafter.

This boiler presents no imposing array of hand hole caps to leak or remove and clean, nor cast-iron parts to fail at the moment when the boiler is most needed.

No grotesquely bent or curved tubes to render inspection and cleaning impossible.

No inadequate water and steam spaces to cause the liquid contents of the boilers to be driven into the cylinders of engines to their destruction, and

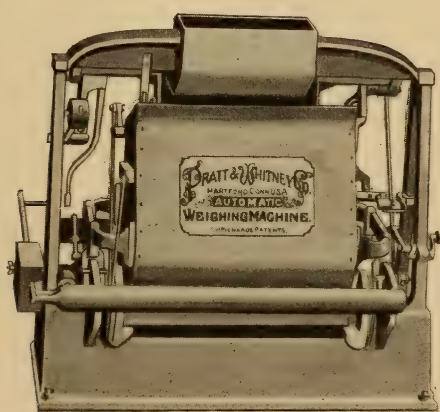
No possibility of the carelessness, ignorance or maliciousness of an employee rendering necessary a new plant and a coroner's inquest.

H. E. Collins & Co.

THE PRATT & WHITNEY CO.'S AUTOMATIC WEIGHING MACHINE.

DIVIDENDS being dependent chiefly upon small economies, especially in the field of industrial engineering and the development of steam power, has led engine builders to improve their engines until these have now reached a high state of refinement. In boilers, also, great improvement has been made, and automatic stokers and other auxiliaries have also been introduced, but these do not begin at the foundation of things, nor give a clear oversight of the fuel pile. To fill this gap the automatic weighing machine shown in the illustration has been devised by Mr. Francis H. Richards. Every user of power ought to know just how much fuel he is burning in his furnace and how much water he is evaporating in his boilers. This machine furnishes a way of estimating these quantities by substituting daily reports for occasional tests made by experts. Besides reporting this data, the weigher makes an impartial record of the manner in which the firemen do their work, and shows whether the boilers are working at their maximum efficiency, whether money is being made or lost in this way.

This automatic weigher is made in many sizes so as to adapt it for a wide range of work. Its operations are controlled by self-regulating devices giving it



extreme accuracy, whether it be made for weighing a few ounces or hundreds of pounds. The registering mechanism is one designed especially for use on this machine; it is positively connected with the valves and with the interlocking safety devices so it cannot falsify the record.

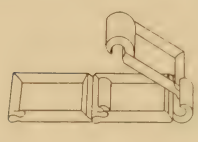
The machine being automatic, when once installed, it weighs out the fuel without requiring further attention. It is a labour-saving appliance that every manufacturer who looks closely to his expense accounts, and who regards both the direct and the indirect economies, will find invaluable. In nearly all cases the aggregate savings will repay the cost in a very short time. Several of these automatic weighers have been ordered for the Duane street station of the Edison Electric Illuminating Company in New York city, and a considerable number are at work in different parts of the country weighing grain and other granular materials. That this machine is placed before the public by such well-known and responsible parties as the Pratt & Whitney Company is a sufficient assurance of its reliable operation. For further information address the manufacturers at Hartford, Conn.

THE BUILDING OF AN INDUSTRY.

IN 1872 (23 years ago) a young man named William D. Ewart was a partner in a small country supply store, in Belle Plaine, Iowa, a large part of the business of this firm being with the farmers, to whom they sold seeders, mowers and other implements. The self-binding harvester was then in its infancy, and the firm of Ewart & Gore had sold a few machines to their customers. It soon developed that they were unreliable, because the regular order and accurate timing of the complicated motions necessary to bunch and bind the grain could not be secured. The transmission of power to the various parts of the intricate machinery was largely by leather belts, and these stretching in dampness of early morning and contracting in the heat of the day, in spite of almost constant attention, produced results and caused delays disheartening to the farmer and discouraging to the makers of the machines. To overcome this difficulty some of the manufacturers substituted chain, using what is known as the strap link, which consisted of rectangular links of malleable-iron joined together with a piece of hoop iron, which was folded and riveted and, consequently, non-detachable, the hoop iron links alternating with the malleable ones. This chain was crudely made and inaccurate in pitch, and though it worked much better than the leather belts, gave trouble by "climbing" the sprockets and breaking, every break stopping the harvesting till a new link could be riveted into the chain. With thorough knowledge of this and other defects in the mechanism of the Self-Binder, Mr. Ewart designed and undertook the construction of a machine which should be free from them.

WILLIAM DANA EWART.

As one of the details of this machine he invented the detachable drive chain which bears his name—the Ewart Link-Belt. The particular link he designed at this time was then, and has ever since been, known as No. 45. There is evidence of sound mechanical judgment and even prophetic insight in the facts that the dimensions of this link have never been altered and that, though many other sizes were soon regularly manufactured, fully three-fourths of the Link-Belting in use is still No. 45.

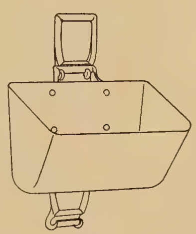


Limited facilities and unforeseen obstacles preventing the successful issue of his work at Belle Plaine, Mr. Ewart removed to Chicago and addressed himself to securing the adoption of his Link-Belt by the makers of harvesting machines, his efforts resulting in the formation of The Ewart Manufacturing Co., with Mr. John C. Coonley, President of the Chicago Malleable Iron Co., as its first President.

Ewart was the first man to realize the importance of accuracy of pitch in the Link-Belt, as well as in the sprocket wheels, and devised numerous ingenious methods to secure it. The fact that his Link-Belt was detachable made it infinitely more desirable than the old strap link. With a few spare links in his tool box, a farmer could start out with his machine and repair the Link-Belt in event of its breaking, without serious loss of time. Its accuracy made it work smoothly and properly, and minimized the danger of breaking, disaster only occurring when it might be reasonably looked for through the collision of the binder with an obstruction or some jamming in the then intricate binding portion of the apparatus.

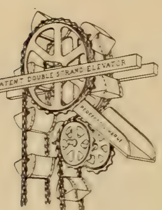
From this little beginning has grown the entire Link-Belt industry of this country and, we may say, of the civilized world. For the first few years of its manufacture the agricultural implement maker was looked upon as the only purchaser of large quantities of Link-Belt. Mr. Ewart, however, foreseeing its use in the elevating and conveying of materials in industrial establishments, began the devising of attachments to which elevator buckets or conveyor slats and flights could be secured.

It seems strange at this day to recall the fact that there was a time, and not so very far in the past either, when the mere question of driving with Link-Belting from one wheel to another was looked upon as a serious problem and by many with apprehension. When the first Link-Belt elevator was put up in one of the grain elevator warehouses in Chicago, the entire expense had to be borne by the Ewart Co. and the running of the apparatus, which would probably not elevate more than 500 bushels an hour, excited the wonder of the millwrights and mechanics who saw it. All kinds of dire prophecies were made : "It would wear out quickly," said one ; "it will stretch and jump off the wheels," said another ; "the rust will get in the grain and ruin it," suggested a third, and so on until every feature of the real excellence of Link-Belting was condemned in turn, and so overwhelming was the denunciation in spite of the fact that it worked perfectly, that the elevator was not used and eighteen months after its first introduction the writer saw it idle, covered with rust, and looked upon as an encumbrance. A second elevator had been erected, but owing to the imperfect fitting of the wooden casing, and the buckets being too closely confined, it had broken down a number of times and was finally thrown into the scrap heap. The next year, however, saw quite a change in the state of affairs : over thirty elevators and about as many conveyors, though all of small sizes, were successfully installed, not, however, without a great deal of difficulty, mechanical and financial ; but still enough had been done to place what is known in the trade as the "transient" uses of Link-Belting as contrasted with the agricultural, on a firm basis. The Ewart Manufacturing Co. in a small way continued this line of trade, strictly adhering to the policy of selling only the component parts of an apparatus, leaving the work of erection and all the necessary tinkering and annoyance to the customer, the Ewart Manufacturing Co. simply guaranteeing the working strain of the Link-Belt and its accuracy. Gradually the number of sprocket wheel patterns increased and as the business developed, it became more and more apparent that it was necessary for some association to have the development of the Link-Belt business in manufacturing plants solely under its care. With this end in view, Mr. Ewart organized The Link-Belt Machinery Co., of Chicago, and established agents in the Eastern States. The Machinery Co. opened a branch in New York City, and the trade in and about Philadelphia was cared for by the firm of Burr & Dodge. In 1888 this firm and the New York Branch of the Machinery Co. were united in a company organized as The Link-Belt Engineering Co. The establishment of these companies for the sale of Link-Belt and its kindred devices and the development of their uses, naturally led to the expansion of the business to its now very large proportions and the devising of a great many new applications.



In the development of this industry and in response to demands and possibilities of the business a great many inventions have been given birth. From the first form of elevator, which consisted of a single strand of Link-Belting with buckets attached to it at intervals, have grown many modifications ; among them the double strand elevator, *i. e.*, two strands of Link-Belting on the back of the buckets, which was made necessary by the use of larger buckets at a time when the Link-Belting was comparatively

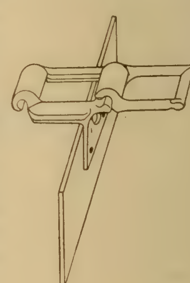
small, and the centrally hung bucket elevator, which has two strands of Link-Belting set edge-wise at the ends of the buckets, thus permitting the steadying of the buckets in their upward and downward paths, by running the Link-Belting between guides. This arrangement of the chains has made it possible to construct what is known as the Perfect-discharge Elevator, in which



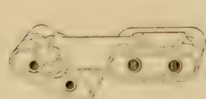
the buckets and Link-Belts in their downward path and directly under the head wheel, are deflected underwards so that the spout receiving the delivery from the buckets can be placed somewhat under them as they discharge, making it practicable to run at much lower speed than is required when the buckets are placed on the face of the Link-Belting and rely upon centrifugal force as well as gravity to empty their contents.

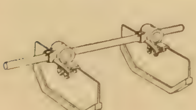
These forms and many others were devised and introduced by the Link-belt Companies. The invention of the traction wheel for the head of elevators (the traction wheel being one without sprockets) was due to the difficulty experienced at the Franklin Sugar Refinery, in Philadelphia, a number of years ago in elevating ashes. The Link-Belt elevator when supplied with the sprocket head wheel wore out very rapidly, but by the substitution of a traction, or smooth, wheel its life was increased nearly four-fold.

In chain conveyors the development has been equally great. From a line of small malleable-iron Link-Belt with wooden slats 6″ long x 2″ deep, the conveyor has developed until at present there are a number in use in the coal regions with flights or scrapers 4 ft. long and 12″ to 18″ deep, having a capacity of from twelve to fifteen tons of lump coal per minute.



When service requirements passed beyond the strength of cast malleable links of the Ewart form, the Giant chain was devised and put upon the market. This chain would be classified with that formed of alternate single and double bars punched and riveted together, now almost obsolete ; but differed from it in being so designed that the wearing surfaces were independent of the rivets. It proved durable as well as strong and for a number of years was extensively employed in log hauls and other heavy duty. Progressive demand in the line of combined lightness and strength was next met by the invention of the Dodge Chain. This is a wrought-iron cable chain with links of long pitch, between the joints of which are inserted malleable-iron bearing blocks, designed to increase the bearing surfaces in the articulation of the chain and make at the same time a suitable resistance to the action of the sprockets of the driving wheels. The Dodge chain has been more extensively used for heavy duty than any form of large Link-Belting in the world and has become the standard of excellence in its field. Within the past year the Monobar has been developed, and it will undoubtedly be largely used in the future in the same line of work that the Dodge chain has so well performed. The Monobar is a series of bolts flexibly connected to each other by malleable-iron bearings. It is lighter and stronger than the Dodge chain and possesses at the same time large bearing and sprocket surfaces. So through all the years from the date of Ewart's first invention of Link-Belting the Ewart Co. and the Link-Belt Companies have striven to improve





their manufactures, more fully meet the requirements of their customers, and always present the best possible device to the engineering and mechanical world, clinging to nothing old if a new and better device could be obtained.

The growth of the Link-Belt Companies in the line of engineering as contrasted with merchandising, has been stimulated by the inventive and mechanical progress made in perfecting their appliances. Orders for material bought on the judgment of their customers are exceeded in volume and importance by the business resulting from problems submitted by their clients and solved by their Engineering Departments. The question of cost per foot or per pound of the machinery has been largely superseded by the broader queries—what tonnage will it handle and at what cost per ton, what manual labor can be saved by its introduction, what will be the cost of maintenance, operation and repair. It is an interesting fact that in modern engineering practice the cost of non-productive labor relative to productive is becoming greater all the time. In the Link-Belt Companies the designing, draughting, accounting and general expenses fully equal the pay rolls of the workmen. The necessity for completing drawings to the minutest detail has only been recognized of late years. The old fashioned machine shop practice left to the individual workman the devising of many of the little details, under the mistaken notion that the little things were of little importance, and the fact dawned upon the engineering world slowly that it is the little detail that is frequently the most important to the operation and value of a device.

There is no difficulty in elevating and conveying material after the load is fairly in front of the scrapers or flights or in the buckets. It is the loading and discharging points that demand skill and experience. Realization of this has led to the construction of terminals of elevators and conveyors by the companies and to the employment of iron and steel in these supporting structures, and the consequent equipment of large departments in their works for iron and steel construction, which now enable them to ship even large installations in such completeness as to leave little but the assembling to be done at destination.

The growth of the Link-Belt business has been so rapid and its diversity so great in the last few years that catalogues have proved wholly inadequate to its uses. Photography has been largely employed as an auxiliary, but finds its chief value in suggestion, as local conditions modify design to such an extent that identical accomplishment is often obtained by very unlike devices. The Link-Belt Companies seek problems in the elevating and conveying of materials, raw or finished, in bulk or in package, and apply to their solution the facilities of shops amply equipped with modern tools, the ability of trained engineers, and the experience gained in the building of an industry.

James M. Dodge.

FOUR NEW TURBINES FOR NIAGARA.

THE site for the new power plant of the Niagara Falls Hydraulic Power and Manufacturing Company is being cleared, upon which a building 60 by 160 feet when completed will be constructed. There have been contracted four of the James Leffel specially designed, double discharge horizontal shaft turbines of 8000 horse-power, to be placed in the new power building. These turbines will operate under a head of 205 to 220 feet, the pressure being the highest under which water has ever being used for power purposes in so large a quantity upon each wheel. The turbines are being built by James Leffel & Co. of Springfield, Ohio, who have designed and detailed these specially for this plant. This Turbine Company has made a specialty of water wheel work for more than a third of a century, during which time they have brought their turbine to the highest state of perfection, and are building the finest grade in the greatest variety of designs. There are in successful operation, in the paper company adjoining the new property, two water wheels of the same style and character of 1200 horse-power each, which were purchased four years ago, and may be seen in daily operation.

The new turbines will be of 74 inches diameter, to conform to the speed of the electric generators, to which they will be attached direct, without gearing or belting. They will make 250 revolutions per minute, a powerful generator being applied on each side, or at each end of each wheel shaft, making 8 generators in all driven by the four wheels. The power will be taken by wire over the cliff and distributed to consumers for different purposes. The illustration herewith shows the runner of the Leffel wheels now in operation, which will be improved in design for the new and more powerful turbines. The central hub and web will be of iron, and the circumference or bucket part a quality of bronze equal in toughness and elasticity to steel. This bucket portion will be most securely fastened to the solid web flange surrounding the hub. The gates are made of steel, nicely balanced, and will be easily moved with a strong, simple and solid operating arrangement. The outer casing surrounding wheels is 11 feet in diameter, made of heavy cast-iron and steel plates. The water is admitted to the guide chamber through a large pipe underneath the cases, and after operating upon the wheel is discharged laterally on each side, and finally downward through long draft tubes into the tail pit. These wheels will secure a perfect end balance of shaft, preventing any end thrust, admitting no unbalanced pressure on any part of wheel runner.

The feature of direct connection to the electric generators in this new power plant is important in the points of its great simplicity and compactness, its ease of examination and management, its greater rigidity and endurance, and its susceptibility to automatic regulation. The Leffel Company is constructing five ot their improved lateral double discharge water wheels for a Western company, adapted to a head of 140 feet, the same direct connection being applied in this instance. Three of the turbines will drive one electric generator each, and one will drive a generator at each end of its shaft. The same method of direct con-

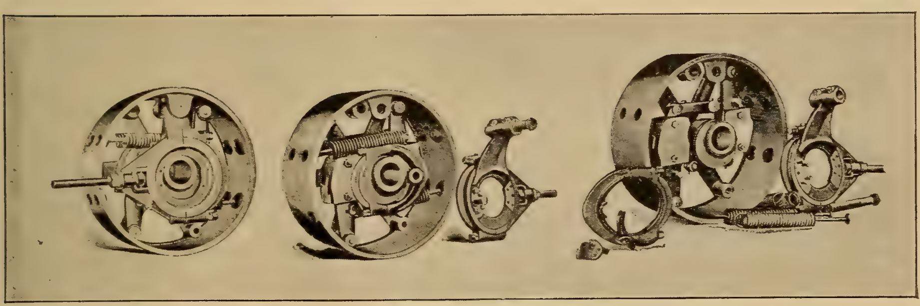
nection to generators is also adopted in a plant of four of the Leffel cascade water wheels for a head of 730 feet, situated at Ward, Col.; and in a new plant at Spokane, Wash., of four of their improved horizontal turbines.

The long experience and practice of the James Leffel Company, in their specialty of high grade turbines for great heads and heavy duty, enables them to undertake with every confidence of success, the design and construction of any water wheel plant however complicated.

JAMES LEFFEL & Co., Springfield, Ohio.

A RECENT IMPROVEMENT IN ENGINE GOVERNING.

THE wise man who purchases a steam engine will insist upon the engine having all the latest improvements, but unless he has kept himself carefully posted he will be forced to ask, what are the latest improvements? Probably the very latest is the governor shown in the accompanying illustration, both complete and with the eccentric yoke removed. This governor has the usual arrangement of weights and springs, and belongs to that class in which the eccentric swings from a fixed point; and the principal feature is the manner in which the motion of the weights is transmitted to the main eccentric. As is shown in Fig. 3, the weights are connected by links to the ears of the auxiliary eccentric which is fitted to turn upon the hub of the governor wheel, so that as the weights are moved this auxiliary eccentric is turned around the shaft. This auxiliary eccentric is fitted with a yoke or strap, shown in position in Fig. 2, and



removed in Fig. 3. In this yoke is a hole which receives the pin bolted to the main eccentric in Fig. 2. Thus as the auxiliary eccentric is turned around the shaft, its yoke is thrown across, carrying with it the main eccentric, which is thus moved nearer to or farther from the centre, and thereby decreasing or increasing its throw. The advantages of this combination are that the governor is mechanically locked in every position it assumes, and can only be moved by pulling the weights, the pull of the valve having no effect whatever.

To reverse the governor the pin bolt to the main eccentric is changed to the holes shown on the opposite side in Fig. 2, the weights and springs are changed to the holes provided for them, and the operation is complete. The governor is compact, all adjustable parts are accessible, and the wear is taken up by two simple adjustments.

The governor was designed and patented by H. C. Clay, Superintendent of our Engineering Department.

THE BROWNELL & Co.,
Dayton, Ohio.

AN ECONOMIC USE OF WATER POWER.

ON page 226 of the article by Dr. Emery, entitled "When is it Advantageous to Use Water Power and Electric Transmission," is an unusually interesting picture of a water wheel installation.

The plant shown is that of the Wanoosnoc Electric Power Company, located about two and one-half miles from the city of Fitchburg, Mass. A pipe line 36 inches in diameter, 1800 feet long, conveys the water to the power station. The plant consists of six double nozzle "Pelton" wheels 28 inches in diameter, enclosed in three cases, which run at a speed of 375 revolutions per minute under 130 feet head, and have a capacity of 500 horse-power. All of the wheels are mounted on the same shaft, which is connected by an insulated coupling to a 300 K. W. Westinghouse 2-phase generator. The entire power could have been furnished as well in a single wheel of larger diameter, but small wheels were necessary in order to give the proper speed to the generator by direct connection. The power thus produced is transmitted at 2250 volts to the Simond Saw Works two and one-half miles distant, and is used for running all the various machinery connected with the works. The "Pelton" differential governor secures close and most sensitive regulation with wide and constant variations of load, maintaining a uniform speed under what are considered the most trying conditions ever met with.

This plant affords a good illustration of the advantages of water power by our system, and indicates the facility and economy with which such sources of power may be everywhere made available.

THE PELTON WATER WHEEL COMPANY,
San Francisco and New York.

PRESERVATION OF BOILERS.

A CORPORATION in Pennsylvania engaged in coal mining on an extensive scale, and having several hundred steam boilers, found themselves short of water suitable for steam making, last summer and fall. It was necessary to run the plants at any cost, but the only source of supply available was water from the mines, and this was heavily charged with sulphur, which, under the influence of the boiler temperature, developed sulphuric acid in sufficient quantity to destroy a boiler in a week's time. The water was pumped into tanks and treated it with quicklime, which neutralised the acid to some extent, but loading the water with vast quantities of scale forming material.

As an experimental test the boilers were treated with a compound, the base of which was a petroleum product, having a vaporising point in excess of the boiler temperature and freed from all tarry and suspended matter. This compound acted by coating the inside of the boiler ever so slightly, but sufficiently to prevent the scale forming mineral from attaching itself to the iron, and being acid proof protected the boiler from the sulphuric acid, which found its way to the boiler in spite of the lime treatment. Individual atoms of scale forming mineral boiling up through the compound were coated with it, and thus prevented from crystallizing into solid matter until they could be removed by blowing down or washing out. The result of this treatment was that the plants were kept going, and not a dollar's worth of injury was done to the boilers, while the cost was very slight.

The compound was furnished by the Pittsburg Boiler Scale Resolvent Co. of Pittsburg, Pa. They guarantee every barrel they sell, and the buyer is judge and jury as to whether he shall pay for it after a fair trial. They also guarantee that it will keep a boiler free from scale and protect it from corrosion at a less cost than by any other method, and their Resolvent is beneficial to cylinder lubrication and to packing. Write for their circular.

PITTSBURG BOILER SCALE RESOLVENT CO.,
Pittsburg, Pa.

ECONOMIC LUBRICATION.

NO steam plant is well regulated, or fitted to be run with economy, if it is not supplied with an oil filter that will keep the oil for lubricating purposes in the best condition. One of the most popular of such filters is the "Finley." It is made of heavy galvanized iron, and contains two water-tight compartments.

The working of this filter is as follows: The waste or dirty oil is poured into the tank at the right side, as shown in the cut on page 82, and as it passes at once through filtering beds is deprived of the larger particles of grit and dirt, and is still further cleansed by rising from the bottom through water. In passing through the entire filter the oil is filtered seven times, but to make the operation sure it is again passed through a filtering process by being poured into the tank at the left, whence it passes through the double T, as shown, rising through water to the final tank. Nothing speaks better than an actual test in ordinary operation, and such a test reported by George S. Gatchell, manager of the Dakota Elevator, Buffalo, showed that three gallons of oil ran an engine 31 hours, and after this oil had been run through a "Finley," the same three gallons ran the same engine 156 hours.

This filter is manufactured by

GENOR BROTHERS MANUFACTURING COMPANY,
97 Washington Street, Buffalo, N. Y.

A REMARKABLE ADVANCE IN DIRECT CURRENT DYNAMO DESIGN.

BUILDERS of dynamo electric machinery have long sought to eliminate armature reaction, the one thing which has been a source of continual annoyance and expense to the owner by reason of sparking at the brushes, which is destructive to the commutator.

The actual results attained by the principal manufacturers may be seen by carefully watching the operation of their machines, and, if the load be a changeable one, the destructive spark will surely be an evidence. With a practically constant load the brushes may be so adjusted as to run with little sparking, but in the modern building with electric elevators to be run, the load is constantly changing and no engineer can be at all times in attendance at the dynamo to adjust the brushes to the proper point as the load changes, and hence more or less sparking occurs.

But a radical change has been wrought through the careful study of the causes leading to these difficulties, and after a long series of experiments made by Prof. Harris, J. Ryan of Cornell University, assisted by Milton E. Thompson, E. E., their labors have been rewarded by a design for a direct current dynamo which is, indeed, well nigh perfection.

The cut, shown on next page, has been made from a photograph of a 50 K. W. Thompson-Ryan Belted Generator, the direct connected type being shown on page 17 of this magazine.

The dynamo is of the multipolar type, having from 10 to 18 poles according to size. The design throughout is a radical departure from the well trodden paths of other manufacturers, and the principal feature of the machine is a set of coils called "balancing coils," which are wound into a slotted cast steel pole ring. These coils are in series with the armature, and entirely neutralize all magnetic effects due to armature currents and give a field of exactly the requisite strength for sparkless commutation. The field coils proper, require only one-fourth the energy usually consumed in ordinary design, and the armature carries from three to four times the depth of copper used in other machines.

The brush holders connected to brass rings of negative and positive polarity insulated from and fastened to the field casting, project outward, and leave the entire outer end of the commutator free and accessible.

The only leads employed on the whole machine are one from the negative brush holder ring to the negative terminal, and another from the positive brush holder ring to the inner end of the balancing coils. The brush holders themselves are very simple, and hold the brushes in such a way that they require no adjustment, but have only to be slipped into the holder. Working with brush holders absolutely fixed, there is entire freedom from sparking and under any or all conditions of load.

The whole brush holder arrangement is adjustable around the commutator, and by loosening the clamp bolts the brushes may be shifted backward or forward. This is only done, however, for the purpose of adjusting the compounding of the machine. By shifting the brushes in this way the machines

may be adjusted through a range of from 10 per cent. drop at full load to 10 per cent. rise, and this without any effect whatever on the commutation.

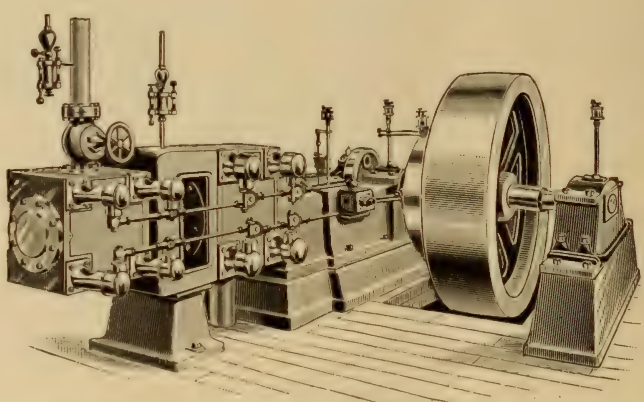
As an example of the high efficiency of this generator we quote the results of a test of a 200 K. W. direct connected machine, viz., one-quarter load, 91 per cent.; one-half load, 94 per cent.; three-fourths load, 95 per cent.; full load, 95 per cent. The unusually high efficiency under light loads, and the very great range of uniform efficiency, is due to the very small fixed losses, the result of the very small field energy consumed and the light core losses.

Another important feature of this dynamo is the great ease with which two or more machines may be worked in parallel. The design of the machine particularly fits it for this sort of service. They may be thrown in parallel while differing widely in voltage produced, and each machine will take its due proportion of the load, notwithstanding the fact that they may be greatly over compounded. Two or more of these machines will work perfectly in parallel, and divide the lightest load evenly or maintain perfect unison with the entire load thrown off.

The Thompson-Ryan dynamo is built in sizes from 12½ K. W. to 1500 K. W. capacity, both belted and direct connected. The manufacturers, J. H. McEwen Mfg. Co., 19 Dey street, New York, state that they will be pleased to furnish handsomely illustrated catalogues of either their engine or dynamo to those who request them.

ATLAS CYCLOIDAL THE NEW ENGINE.

Offered as the Latest and Best Expression of Advancement in the Art of Using Steam.



ATLAS CYCLOIDAL HEAVY DUTY ENGINE.
(TANDEM COMPOUND).

ATLAS ENGINE WORKS,

P. O. Box No. 708,
INDIANAPOLIS, IND.

ADVANCE SHEETS OF CATALOGUE NOW READY.